PB83-109223

National Assessment of the Urban Particulate Problem. Volume VI Philadelphia, Pennsylvania

GCA Corp.
Bedford, MA

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Jun 76

U.S. Department of Commerce
National Technical Information Service
NTIS

PB83-109223

EPA-450/3-76-026d
June 1976

NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

Volume VI - Philadelphia

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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EPA-450/3-76-026d

NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

Volume VI

Philadelphia, Pennsylvania

FINAL REPORT

by

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Contract No. 68-02-1376, Task Order No. 18

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Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
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June 1976

This final report was furnished to the Environmental Protection Agency by the GCA/Technology Division in fulfillment of the requirements under Contract No. 68-02-1376, Task Order No. 18. The contents of this report are reproduced herein as received from the contractor. The opinions, findings and conclusions are those of the authors and not necessarily those of the Environmental Protection Agency.

FOREWORD

This document is part of a 16-volume report assessing the urban particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of the 14 single city volumes that provide working summaries of data gathered in the 14 urban areas during 1974 to support an assessment of the general nature and extent of the TSP problem nationwide. No attempt was made to perform detailed or extensive analyses in each urban area. Rather, the city reports are intended as a collection of pertinent data which collectively form a profile of each urban area. This, in turn contributes to a comparative analysis of data among the 14 areas in an attempt to identify general patterns and factors relating to attainment of the TSP problem nationwide. Such an analysis has been made in Volume I of the study-National Assessment of the Urban Particulate Problem-National Assessment. The reader is referred to this volume as the summary document where the data is collectively analyzed.

This and the other 13 city reports are viewed primarily as working documents; thus, no effort was made to incorporate all the reviewer's comments into the text of the report. The comments were, however, considered during the preparation of Volume I and are included herein in order to alert the reader to different points of view. The 16 volumes comprising the overall study are as follows:

Volume	I - National Assessment of the Urban Particulate Problem
Volume	II - Particle Characterization
Volume	III - Denver
Volume	IV - Birmingham
Volume	V - Baltimore
Volume	VI - Philadelphia
Volume	VII - Chattanooga
Volume	IX - Oklahoma City
Volume	X - Seattle
Volume	XI - Cincinnati
Volume	XII - Cleveland
Volume	XIII - San Francisco
Volume	XIV - Miami
Volume	XV - St. Louis
Volume	XVI - Providence

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ACKNOWLEDGMENTS

GCA/Technology Division wishes to sincerely thank those persons and organizations who made significant contributions to this effort. On-going project supervision was provided by Thompson G. Pace of EPA's Control Programs Development Division. The case study in Philadelphia was greatly assisted by the cooperation and helpfulness of the staff of the Philadelphia Air Management Services, particularly Clemens Lazenka, Larry Himmelstein, Jim Ickes, Alan Tractenberg, Fred Hauptman, Norman Glazer, and William Miller.

EXECUTIVE SUMMARY

The report summarized herein presents the analyses of the particulate situation in the City of Philadelphia conducted as part of the study for the national assessment of the problem of attainment or nonattainment of the National Ambient Air Quality Standards for particulates. The City of Philadelphia represents a highly industrialized area, with above average heating requirements and an average amount of rain, that has had some success in reducing emissions and particulate concentrations though the standards have not been attained. Auto-related factors have been implicated as a major contributing source to the ambient levels of particulates in Philadelphia so this report provides special emphasis in that area.

In addition to the analyses of traffic-related emissions, analyses of the air quality levels, emissions, regulations, monitoring network, meteorology, and construction are included in this report. The major findings in each of these areas are summarized below in the order in which they appear in the text.

AIR QUALITY

The trends in citywide TSP levels have been consistently down with a total reduction of 45 percent during the past 6 years. However, the primary annual air quality standard is being exceeded at most sites around the city and the secondary annual air quality standard is being exceeded throughout the city. The highest annual geometric mean was 121 $\mu g/m^3$. Violations of the 24-hour standards have also been frequent with the secondary standard exceeded on almost 8 percent of the readings in 1974.

The spatial distribution of the air quality is not easily determined due to the various concentrations measured at nearby stations with different heights. Generally, however, the levels are lower in the suburban areas and highest in the industrial areas to the southwest and northeast of the city. A citywide geometric mean of all stations was 80 $\mu g/m^3$.

EMISSIONS

Reductions in emissions in the past 6 years have been fairly substantial (38 percent) with the largest reductions in the area of power plants (95 percent) and refuse incinerators (56 percent). Much of the reductions at this time was due to conversion from coal to oil and gas and the recent controls on incinerators. A remaining problem may be in the area of fugitive emissions; the site with the highest annual geometric mean was influenced by grain handling and coal storage.

As a result of the reductions in other sources, space heating emissions are currently a major share (44 percent) of the total annual inventoried emissions. This implies a prominent seasonal pattern in the emission levels with potentially almost three times as much emissions in the winter months than in the summer months and a strong dependence of the air quality levels on the severity of the winter. Optical microscopic examination of the hi-vol filters found 8 percent by mass of the identifiable particulate to be from oil soot. This seems to confirm the high levels indicated by the inventory.

The trends in air quality over time have shown a strong correlation with the reduction in emissions. In fact, the citywide improvement in air quality at three monitoring sites has been 20 percent more than would normally be attributed to the emission reductions through rollback calculations. This anomaly is most likely a result of the monitoring siting.

REGULATIONS AND SURVEILLANCE

The sources in the City of Philadelphia are controlled by both the city's regulations and the applicable ones of the Commonwealth of Pennsylvania. Enforcement is pursued for whichever regulation most stringently controls the source. Surveillance of the sources are performed through the use of the permit system, visible emissions, and complaints. Only a small amount of stack testing to determine compliance is done; the majority of sources are determined to be in compliance through theoretical calculations. Small residential boilers are one area where some control might be applied.

The regulations imposed by the City of Philadelphia were compared with other cities reviewed to date and were found to be more stringent in most cases. Comparison with average regulations in published studies indicated that the city's regulations were at least as stringent as those normally applied.

NETWORK DESIGN

The monitoring network was found to be generally acceptable except in a couple of instances. The most noticeable omission occurred in the sampling of industrial areas for which it was felt that monitors could be more centrally located in the industrial areas instead of their current semiremote or source specific sites. In addition, the discontinuance of the residential site at the Belmont Filter Station was felt to leave a major area of the city unmonitored and also stopped the provision of valuable information on the air masses entering the city.

METEOROLOGY

Rainfall, windspeed, heating degree days, and the movement of air masses in the area were reviewed and analyzed. Reasonably strong correlation between rainfall and TSP levels and heating degree days and TSP levels

(due to space heating emissions) were found while windspeed showed no real correlation. The general flow of air masses in the region meant that TSP levels were usually elevated with winds from the southwest and depressed with winds from the northeast, the direction of most storms. Suppression, and possible washoff, of particulates were felt to be one reason why an analysis of heavy rainfall indicated substantially reduced concentrations on the first and second day after rain when compared to the 7th day after rain. The pollution roses drawn for the monitoring sites in the city indicate a higher concentration of incoming air from the southerly directions. Preliminary estimates are that incoming air to the city is probably 40 to 50 $\mu g/m^3$ concentration. This presents a major impediment to the attainment of standards.

URBAN ACTIVITY

Construction and traffic-related emissions were considered as part of the analyses of the impact of different urban activities on the air quality. The review of the analysis done on construction activity in Philadelphia provided only a slight indication that construction activity was having a noticeable effect on the ambient levels. Any impact was considered to be only very local (one to two city blocks) and not at all felt on the citywide levels.

The analyses of traffic-related emissions indicated that substantial changes can occur in the measured TSP levels with relocation of samplers closer or further from the road. In addition, the fluctuations in the citywide average daily traffic correlated quite closely with the daily variations in TSP concentration. The impact of traffic on air quality levels is such that the city cannot expect to attain standards unless measures are taken to reduce the impact of traffic-related particulates. One comparison of monitors showed at least a 50 $\mu g/m^3$ impact from traffic-related sources.

CONCLUSIONS

Air quality has been steadily improving in the city; annual average TSP concentrations at the NASN site are down over 100 $\mu g/m^3$ since 1957. However, the annual primary standard was met at only three of the 10 monitors operating throughout 1974. Of these three monitors, all in residential areas of the city, only one met the secondary annual standard with a value of 59 $\mu g/m^3$. The large improvements in air quality have been directly paralleled by reductions in the inventoried emissions due to stringent controls on industry (fabricated metals, machinery, electrical equipment, petroleum) and large incinerators, phasing out of small incinerators and coal burning, and fuel switching in power plants. The lack of attainment of the standards, despite stringent regulations and effective enforcement, reflects the generally high level of TSP entering the city from outlying industrial activity (40 to 50 $\mu g/m^3$) and the activity associated with an urban environment, including space heating and vehicular traffic. Small residential boilers have not been under any control other than visible emission regulations. Vehicular traffic was shown to contribute up to 50 $\mu g/m^3$ to the measured levels of TSP for monitors close to the street. In addition, fugitive emissions from stockpiled materials and a grain-handling operation were believed to be major influences on the monitor with the highest annual geometric mean (122 $\mu g/m^3$).

Thus, it appears that control of particulate matter associated with general urban activity, such as resuspended dust from paved roads and oil soot from space heating may be required in order to attain standards. In addition, fugitive emissions are somewhat a problem. Such regulations may prove untenable from a social or economic viewpoint. Further study is needed to resolve this dilemma and is, in fact, being pursued under a separate study. This report should be considered tentative pending the completion of the further study.

REVIEWERS' COMMENTS

The draft report for each city was submitted to interested EPA, state, and local officials for comment on the contents and findings. Comments of an editorial nature were reconciled; comments of a substantive nature which reflect differences of opinion were compiled and are presented below.

1. In general, the report was found to be somewhat superficial, and in parts, conflicting and contradictory. The fact that the microscopic analysis portion has not been completed may contribute to the lack of perception evident in the conclusions. However, it appears that GCA has missed the mark by a wide margin in making an assessment of the particulate problem. As an example of contradictory analysis, the report states that space heating emissions (which generally have no special controls) are 44 percent of the emissions, and automobiles may account for another 40 percent, and then concludes that further control of traditional emission sources is necessary for attainment of standards.

   In addition, it is shown that the street level samplers in Center City give considerably higher values than roof top samplers and yet it is evident that the roof top samplers would be influenced to the same degree by the industrial emissions.

   How then could industrial emissions be responsible for these levels exceeding the standards? Again, the report states that the existing sites in industrial areas are source specific, but concludes that if the samplers were placed at more general sites in the industrial areas higher results would occur. It would seem that eliminating the effect of dominant sources would lower the values.

   There is also no analysis in the report concerning the relative amounts of industrial particulates that are caused by Philadelphia industry versus suburban industry. Since there is no Philadelphia industry southwest of the International Airport site, it would be obvious to suspect

suburban sources in Delaware County for causing the standard exceedance at this station, especially since the southwest wind direction is the most conducive to high levels of particulates.

As far as the Center City and/or street oriented samplers are concerned, the questions that must be addressed are: "Where should the measurement be made? Are we truly measuring 'suspended dust' if this value decreases substantially within 30 or 40 feet elevation? How hazardous is this street level dust? What is the particulate size range? How much is respirable?" It would seem that only roof top sampling should be employed, at least 40 or 50 feet above street level, to measure the deleterious health potential of the suspended particulate in center city.

There undoubtedly is an unresolved problem in certain industrial areas of the city. Some of this may be alleviated by the recent retirement of the batch type municipal incinerators. However, extensive analyses and special control efforts must be expended in these areas if primary and secondary standards are to be met. This may or may not require revisions to current regulations, but that decision can only be made after thorough analysis and substantiation of the reasons for exceeding standards. It also simply may be impossible to comply with the national standards in the industrial and commercial areas based on the HVAS measurement.

In conclusion, the GCA Report has shed little, if any, new light on the problem of particulates in Philadelphia; nor has it provided any useful direction to an eventual solution. If anything, the report again points out the need for review and additional specificity related to sampling methodology and siting criteria, as well as for re-examination and appropriate restatement of particulate standards in terms of exposure and particle size-concentration relationships. The continued measurement of particulate matter by the high volume air sampler remains a handicap to air quality planning. The measurement technique is too coarse, too nonrepresentative, and too subject to error to allow fine point analysis, or to estimate changes in control strategies that are required to meet standards.

I hope these comments will be given full consideration for incorporation in the final GCA study report and that EPA will undertake the necessary actions to address and resolve the many problems presently being encountered in air quality analysis. I would appreciate receiving a copy of the final report as soon as possible, as well as the opportunity to provide further comment as we fell appropriate.

2. The general maximum grain loading rate imposed by the Commonwealth of Pennsylvania is a very stringent effluent gas loading standard.

Editor's Note:

Comments on the draft report by reviewer number 1 have been included in their entirety even though some obvious omissions and contradictions in the earlier draft have been subsequently corrected. As mentioned in the Foreword, this report is intended as a working summary of the data gathered in Philadelphia, for inclusion in a summary report. This report (Volume I - National Assessment) evaluates and balances the data from each of the 14 urban areas studied and draws general conclusions about the urban particulate problem. It is beyond the scope of either document to develop the field study data necessary to answer the interurban transport question. Likewise, such guidelines as "where should the (hi-vol) measurement be made" are being addressed by the appropriate EPA staff, but are not a part of this study.

SECTION I

STATEMENT OF THE PROBLEM

The Metropolitan Philadelphia Interstate Air Quality Control Region (AQCR) lies along the Delaware River basin and encompasses 11 counties from three states and two EPA Regions (Figure 1). While the major center of population in the area is Philadelphia, the fourth largest Standard Metropolitan Statistical Area (SMSA) in the country, the AQCR also contains the SMSA's of Trenton, New Jersey, and Wilmington, Delaware, with populations of one-third and one-half million respectively. The major topographical feature of the area is the Delaware River which separates the Pennsylvania and Delaware portions of the AQCR from the State of New Jersey. The region lies near the path of low pressure systems which move across the country, resulting in changeable winds and weather in the region. The annual prevailing wind direction is from the west-southwest with the prevailing winds for the summer months being from the southwest and northwesterly winds prevailing during the winter. The proximity of the Delaware Bay helps to moderate temperatures, often encouraging the city heat island effect to change snow to rain, and also adds to the humidity in the summer months with the prevalence of maritime air. Precipitation occurs frequently but moderately, averaging about 41 inches per year. Philadelphia experiences some degree of inversion on approximately 200 days each year; however, on only about 5 days is there insubstantial heating and the inversion becomes relatively severe.

The city is quite highly industrialized, ranking third in the nation for overall manufacturing and first in the production of textiles, ships, and radios. Nevertheless, the inventoried emissions in the area indicate

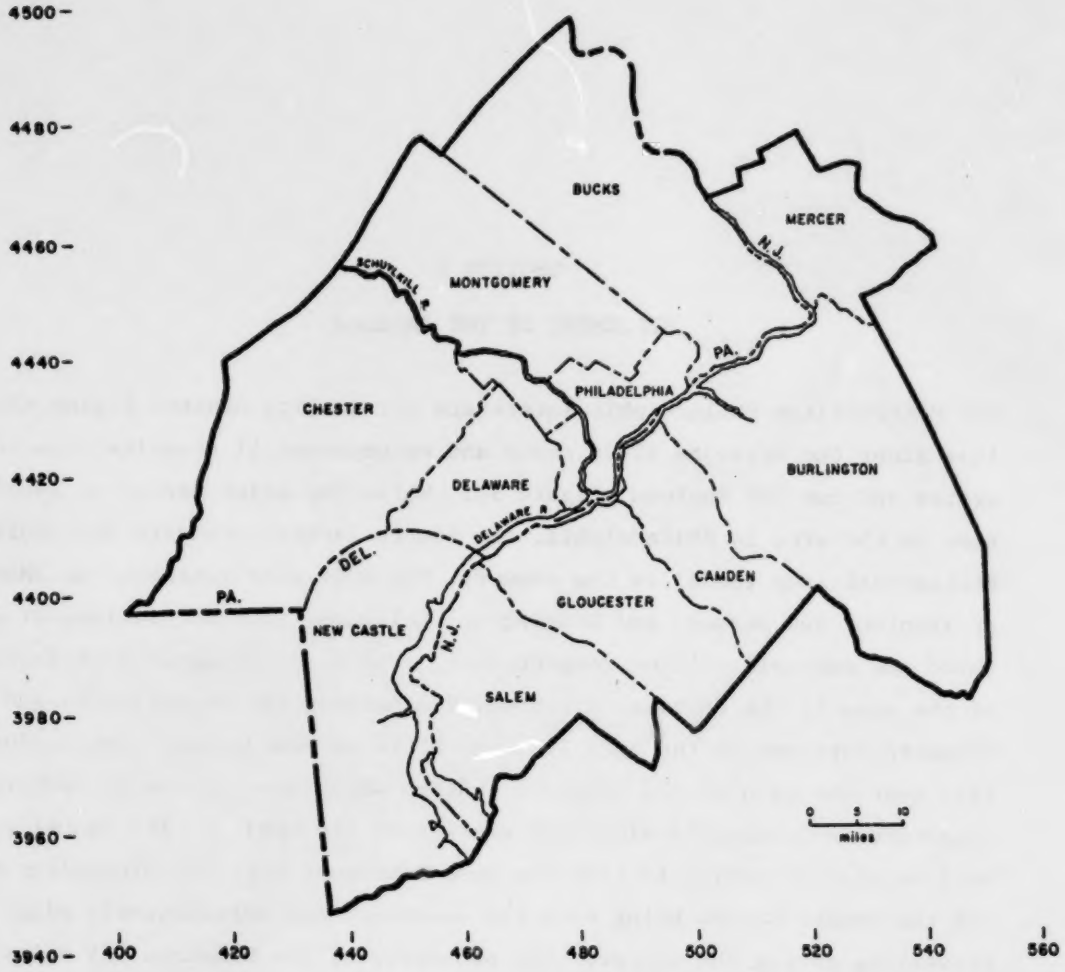


Figure 1. Metropolitan Philadelphia Interstate Air Quality Control Region

that space heating is currently the largest source category in the city, amounting to 44 percent of the total emissions, with industrial processes contributing 30 percent. The long standing control program in the Philadelphia area has resulted in substantial reductions in the emission levels of various source categories, especially power generation and industrial processes, with a composite reduction of 38 percent being achieved since 1969. Other activities thought to add to the total particulate emissions include the demolition and construction associated with the major urban renewal project underway and Interstates 95 and 695. In addition, recent studies in Philadelphia have tended to implicate the automobile and its usage as contributing particularly significant amounts of particulates at low level.

Concentrations of TSP in the ambient air have shown a fairly steady decrease since the early 1960's with the decrease leveling off in the past couple of years. The national annual secondary standard is generally being exceeded throughout the city with levels increasing closer to the center city area. Several sites have TSP annual mean concentrations exceeding levels of 100 $\mu g/m^3$ in 1974.

AIR QUALITY SUMMARY

At least some air quality data is reported in SAROAD for 28 stations in the Metropolitan Philadelphia AQCR; twelve of these sites are located in Philadelphia. All of the sites in Philadelphia are operated by the City of Philadelphia Air Management Services (AMS), with one of the sites being a CAMP station. The locations of the sites in Philadelphia are shown in Figure 2. Specific information on the monitoring sites in Philadelphia is given in Table 1. Most of the sites are in commercial to light industry areas with two in primarily residential areas and one being apparently source specific. None of the sites appear to be really monitoring the air quality in a predominantly industrial area. The height above ground varies from trailer top height (11-13 feet) for 10 of the stations to the top of a three-story building (35 feet).

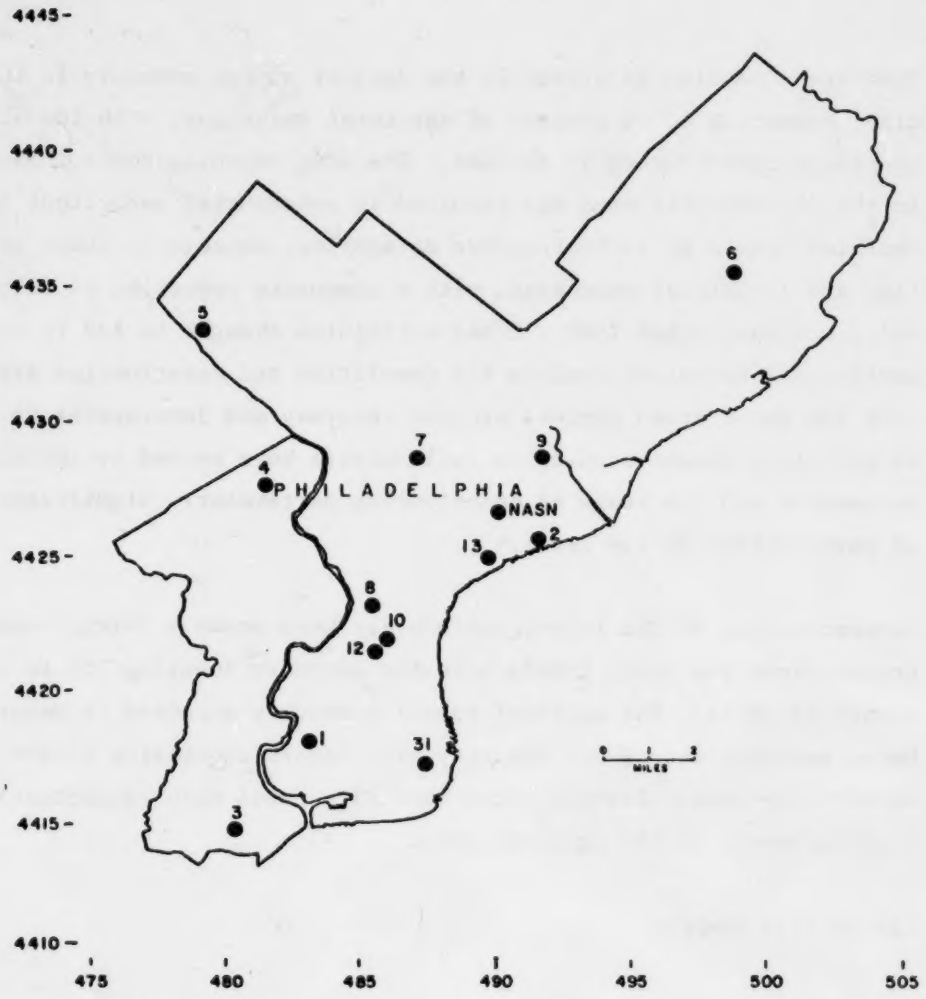


Figure 2. Location of monitoring sites in Philadelphia County

Table 1. CHARACTERISTICS OF MONITORING SITES IN THE CITY OF PHILADELPHIA

No.	AMS code	Address	Height (feet)	Site characteristic	TSP 1974 geometric mean	% of observations above the 24-hour standards	
						Primary	Secondary
1	DEF	Defense Supply Depot	13	Suburban-industrial	105	0	19
2	ALL	Allegheny Ave. & Delaware River	13	Suburban-industrial	122	8	31
3	INT	International Airport	13	Suburban-industrial	94	0	19
4	BEL	Belmont Filter Station	13	Suburban-residential	72	0	0
5	ROX	Roxborough Filter Station	13	Suburban-residential	59	0	0
6	N/E	Northeast Airport	13	Suburban-residential	64	0	4
7	NBR	North Broad & Butler	13	Center city-commercial	NA	NA	NA
8	FRI	Franklin Institute (CAMP)	11	Center city-commercial	119	4	30
9	AMS	AMS Lab	17	Suburban-residential	78	0	8
10	SBR	South Broad & Spruce	13	Center city-commercial	NA	NA	NA
11	S/E	Southeast Water Pollution Control Facility	3	Suburban-industrial	78	>1	3
12	500	500 S. Broad	35	Center city-commercial	76	>1	2
13	AFS	Aramingo Fire Station	30	Center city-industrial	NA	NA	NA
NASN		3200 Frankford Avenue	30	Center city-industrial	NA	NA	NA

Note: NA - not applicable due to incomplete sampling.

Trends in ambient TSP concentration over the years have been fairly constantly downward. The National Air Sampling Network (NASN) monitor recorded more than a 55 percent decrease in emissions from the time it started in 1957 recording 196 $\mu g/m^3$ to its closing date at the end of 1973 with an annual geometric mean of 87 $\mu g/m^3$. A similar decline was seen at the AMS operated station at 500 South Broad which averaged 130 $\mu g/m^3$ in 1960 and 76 $\mu g/m^3$ in 1974, a 42 percent decline. The majority of this decline occurred in the 1966-74 time frame. These, and other, trends are plotted in Figure 3. A smoothed trend plot for particulates, used by the AMS, giving a smoothed graph of composite values as available is given in Figure 4.

The recent (1973) expansion of the monitoring network has located more monitors in areas with high concentrations and also in the lower concentration, residential areas. The net result of this expanded monitoring network is a citywide geometric mean concentration of 80 $\mu g/m^3$. The spatial distribution of the TSP levels can be estimated from the plot of the 1974 geometric means given in Figure 5.

As can be seen from this figure, the national primary annual air quality standard for particulates (75 $\mu g/m^3$) was exceeded at seven of the ten stations that operated throughout the year and the secondary annual standard (60 $\mu g/m^3$) was met by only one of the stations. For the 24-hour standards, out of a total number of observations of 1,253, the primary (260 $\mu g/m^3$) and secondary (150 $\mu g/m^3$) standards were exceeded 8 and 96 times respectively. Half of the violations of the primary 24-hour standard were observed at one station (Allegheny) which sampled only 52 times during the year.

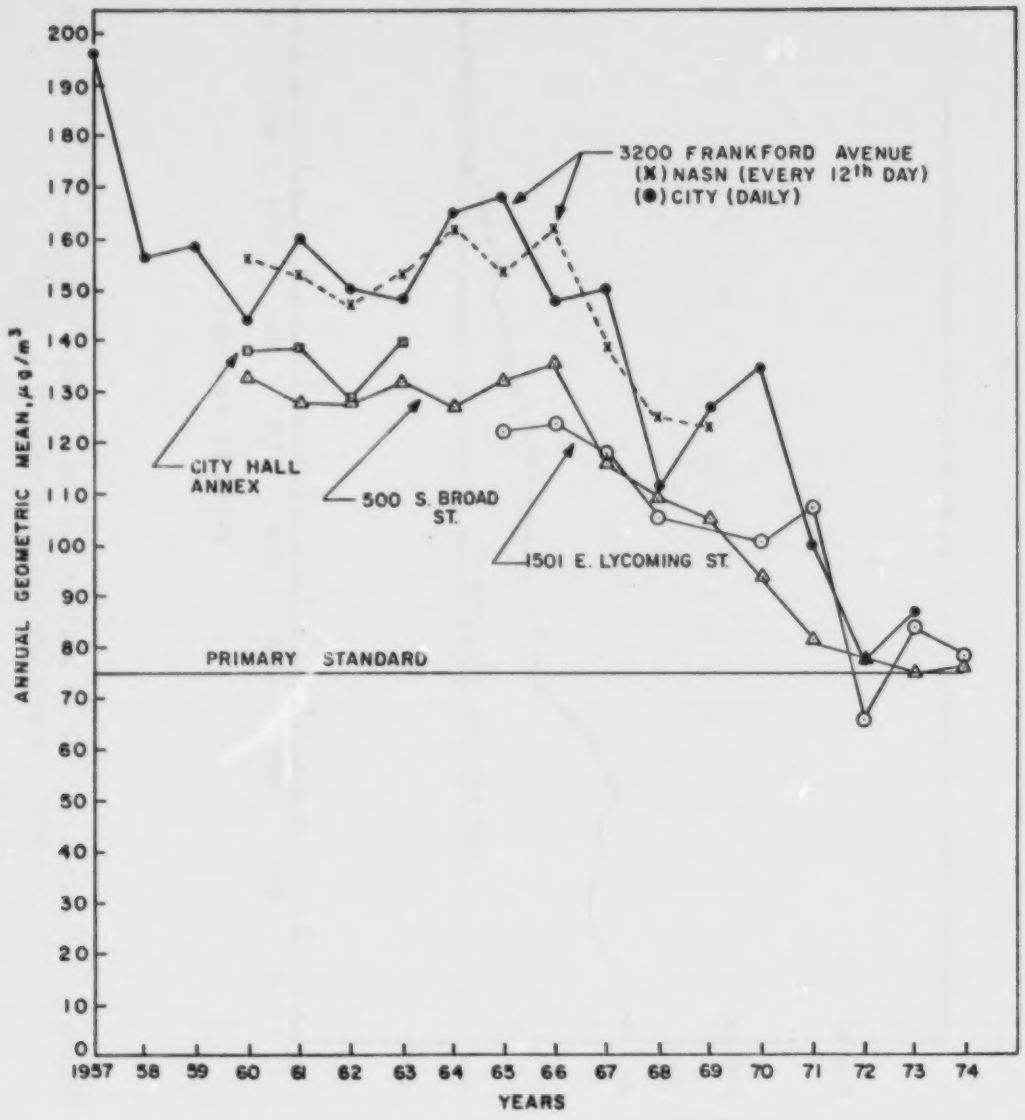


Figure 3. Trends in annual geometric mean for particulates, Philadelphia

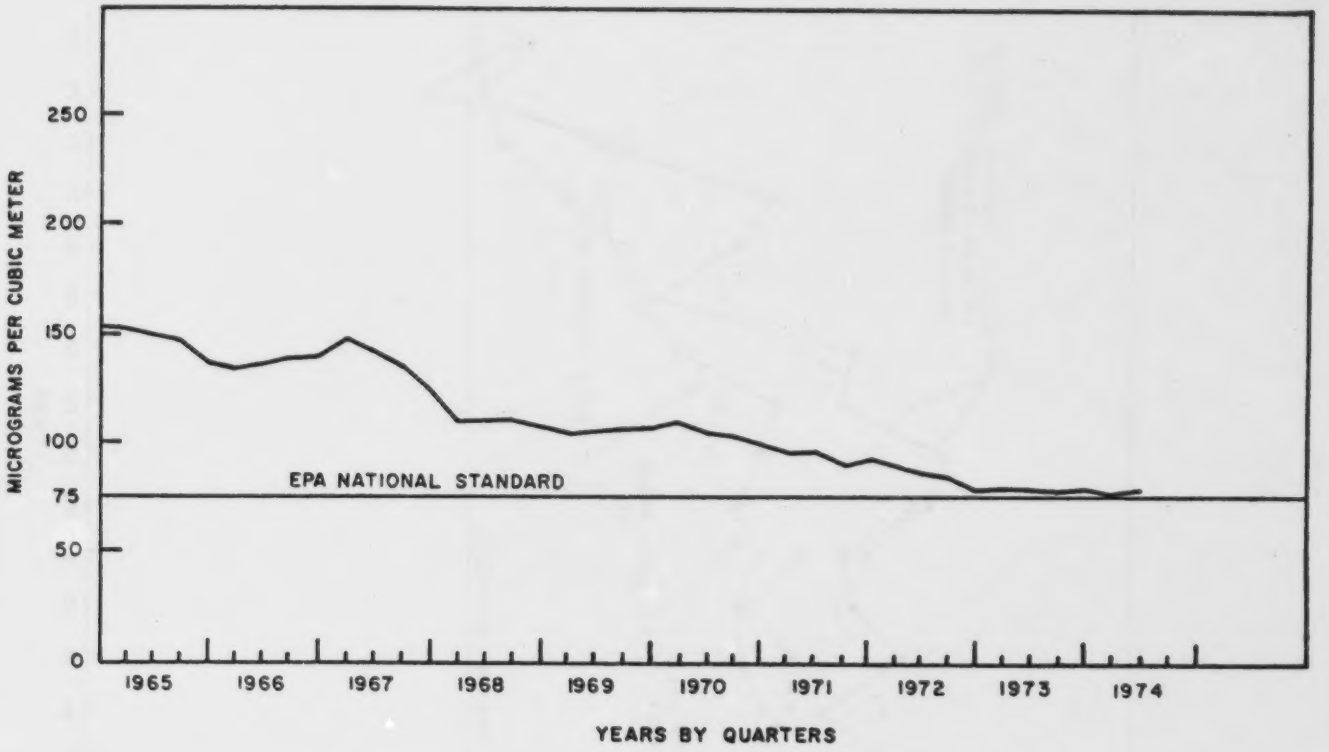


Figure 4. Trends in city-wide average (as available) of suspended particulate matter in Philadelphia, 4-quarter moving geometric average

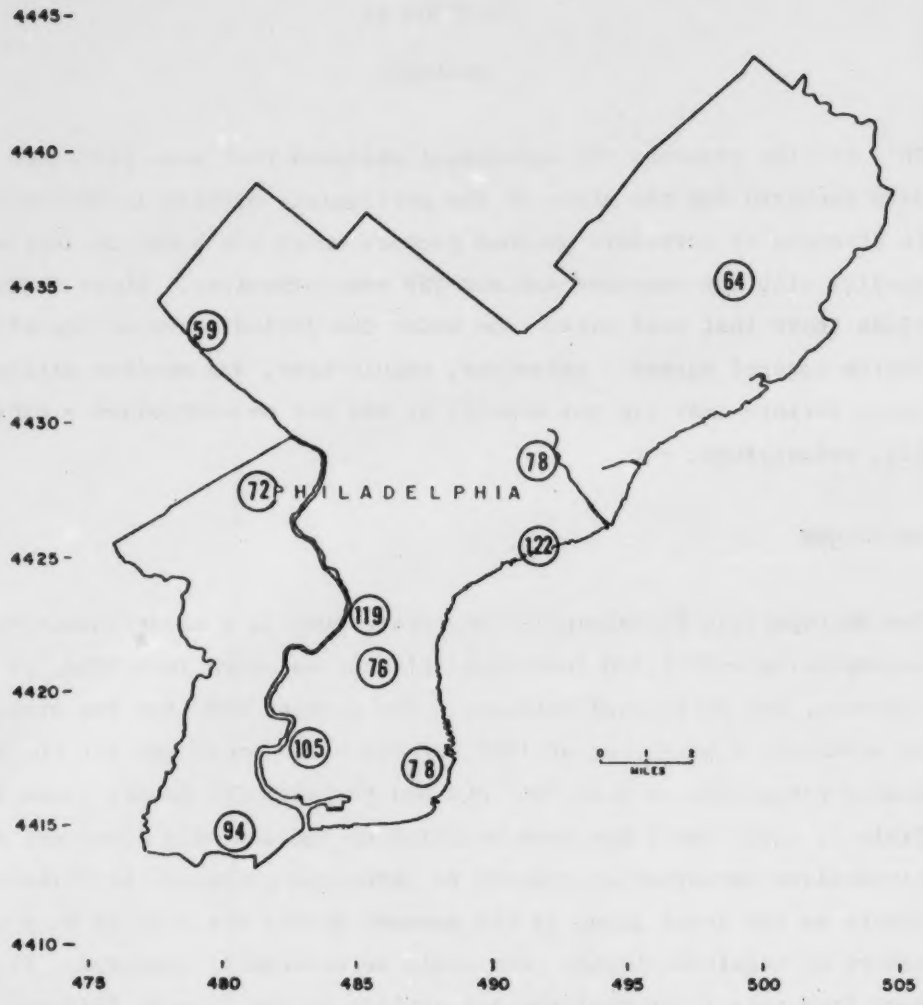


Figure 5. TSP annual geometric means at monitoring stations in Philadelphia, 1974

SECTION II

ANALYSES

This section presents the individual analyses that were performed on the data gathered for the study of the particulate problem in Philadelphia. It attempts to correlate various factors which are known to influence air quality with the measured ambient TSP concentrations. These factors include those that most often come under the jurisdiction of the air pollution control agency - emissions, regulations, and monitor siting - and other factors that are not usually or can not be controlled - urban activity, meteorology, etc.

EMISSIONS

The Metropolitan Philadelphia Interstate AQCR is a major industrial area encompassing over 1,300 individual plants, as coded into NEDS, in Pennsylvania, New Jersey and Delaware. The current NEDS for the area, which is primarily a base year of 1972, provides the breakdown for the different source categories in both the AQCR and Philadelphia County given in Table 2. This table has been modified to include only 1 percent of the particulate emissions attributed to petroleum processes in Philadelphia County as the level given in the summary sheets was felt to be a couple of orders of magnitude higher than could be reasonably expected. It is evident from this table that the air quality in the City of Philadelphia may be substantially influenced by the emissions in other counties in the AQCR since 85 percent of the total inventoried emissions are outside of the city.

Table 2. NEDS TSP EMISSIONS FOR PHILADELPHIA AQCR AND PHILADELPHIA COUNTY (IN TONS PER YEAR)

	Philadelphia AQCR			Philadelphia County			County percent of AQCR
	Point	Area	Total	Point	Area	Total	
Fuel combustion	(133,440)	(31,463)	(164,903)	(9,135)	(8,923)	(18,058)	(11)
External	133,410	31,463	164,873	9,135	8,923	18,058	11
Residential	-	6,334	6,334	-	1,926	1,926	30
Electrical	12,954	-	12,954	944	-	944	7
Industrial	114,341	19,729	134,070	3,954	6,082	10,036	7
C-T	6,115	5,400	11,515	4,237	1,915	6,152	53
Internal	30	-	30	-	-	-	0
Industrial process	(61,322)	-	(61,322)	(9,439)	-	(9,439)	(15)
Chemical	1,810	-	1,810	127	-	127	7
Food/agriculture	1,665	-	1,665	1,520	-	1,520	91
Metals	9,195	-	9,195	383	-	383	4
Mineral	22,521	-	22,521	1,224	-	1,224	5
Petroleum	26,116	-	26,116	6,182[a]	-	6,182	24
Other	15	-	15	3	-	3	20
Solid waste disposal	(8,989)	(6,989)	(15,978)	(5,158)	-	(5,158)	(32)
Government	8,651	-	8,651	5,078	-	5,078	59
Residential	-	1,415	1,415	-	-	-	0
C-T	5	4,906	4,911	5	-	5	0
Industrial	333	668	1,001	75	-	75	7
Transportation	-	(23,074)	(23,074)	-	(7,074)	(7,074)	(31)
Gasoline	-	17,857	17,857	-	5,596	5,596	31
Diesel	-	2,912	2,912	-	946	946	32
Aircraft	-	1,022	1,022	-	347	347	34
Vessels	-	1,283	1,283	-	185	185	14
Miscellaneous	-	36	36	-	-	-	0
Totals	203,751	61,526	265,277	23,732	15,997	39,729	15
% of combined	77	23	100	60	40	100	-

[a] One percent of NEDS summary total.

The spatial distribution of the point source NEDS emissions, which are thought to be in good agreement with the emission inventory for the city maintained by the AMS, is given in Figure 6. This figure provides an estimate of the emission density attributable to point sources if these emissions were considered to be smoothed over the adjoining areas using a weighting process. As may be seen from this figure, there are two primarily industrial areas in Philadelphia, one in the southwest and one in the northeast portion of the city. The southwestern industrial area primarily contains petroleum refineries while the area northeast of the city contains many metal processing and reclamation plants, several incinerators, and some chemical industries. The emissions from the fifty largest sources in the Philadelphia area are graphically located in Figure 7.

The above NEDS data does not include any estimate of the emissions from possible fugitive dust sources. A calculation of the preliminary data supplied from the MRI study[1] of dirt roads, dirt airstrips, construction, and agricultural tilling indicated that the fugitive dust emissions from these sources contributes over 10 times the total tonnage as the inventoried emissions. The majority of this is contributed from dirt roads and construction activity (see Table 3).

In Philadelphia County, construction activity, which is 99 percent of the fugitive emissions, is supposed to be a source of over 290,000 tons per year of particulates, or more than seven times the emissions from all other sources in the county. This is a source which has been getting increased attention by the AMS and may be controlled to a greater extent than the calculated statewide emission factor would indicate. The potential impact of this large source category is considered below in the review of emission trends and later in the analysis of construction activity near monitoring sites.

The AMS has compiled and maintained its own emission inventory for the City of Philadelphia and has recently updated its past emission inventories to ensure that all inventories had comparable inputs. This updated set of

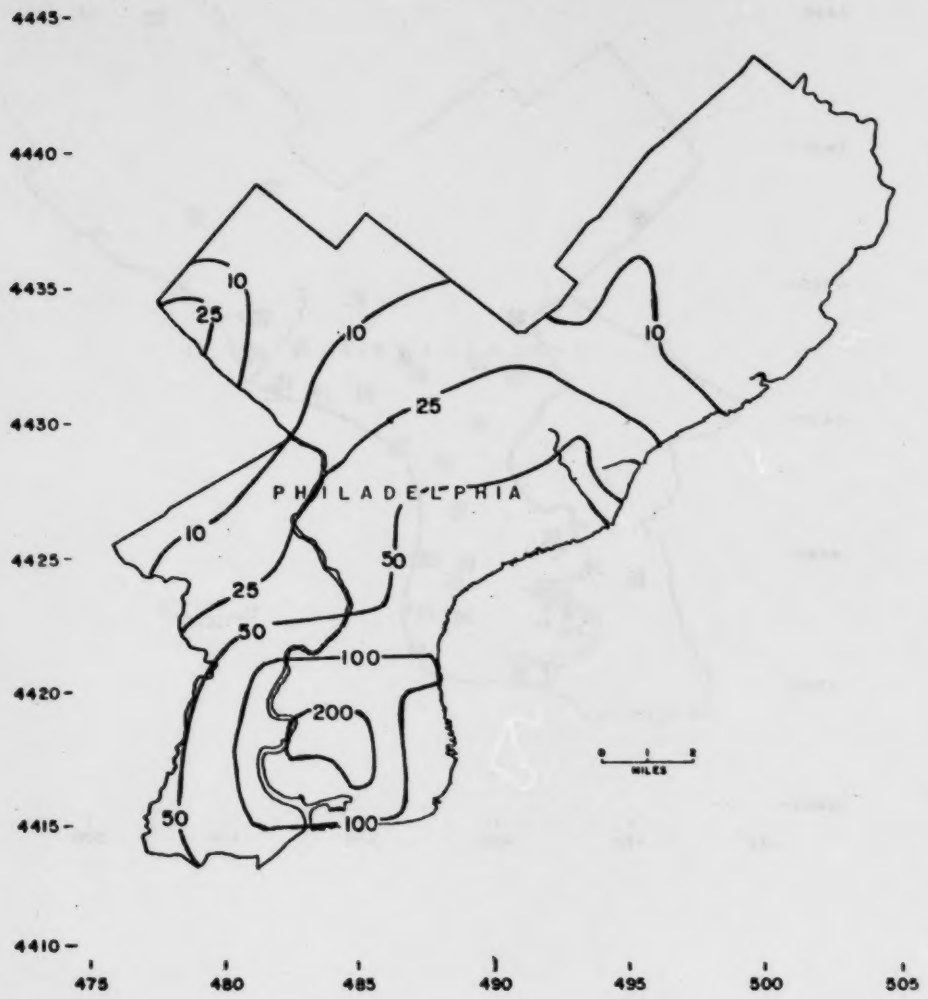


Figure 6. Smoothed point source emission density in Philadelphia (TPY/km^2)

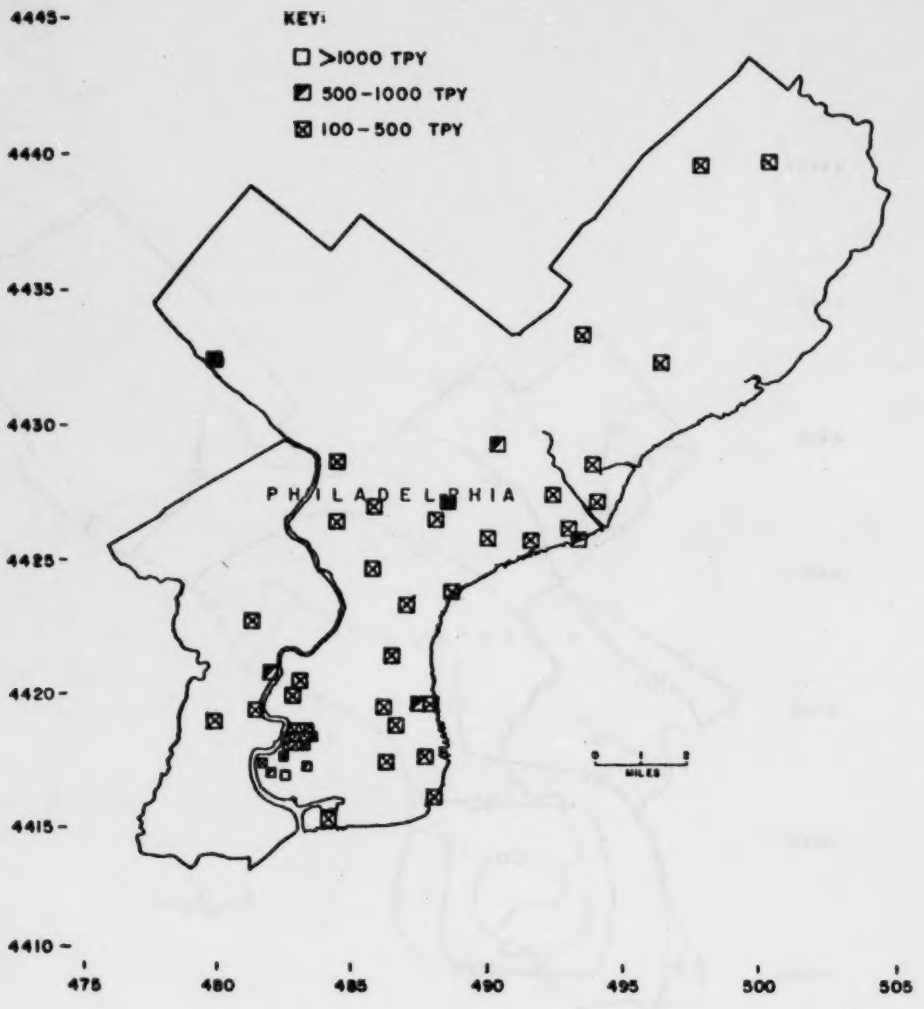


Figure 7. Location of major (greater than 100 TPY) sources in Philadelphia

Table 3. FUGITIVE EMISSIONS IN THE METROPOLITAN PHILADELPHIA AQCR (IN TONS PER YEAR)[a]

	Dirt roads	Dirt airstrips	Construction	Agricultural tilling	Total	County percent of AQCR
Delaware -						
New Castle	8,985	0	13,256	291	22,532	1
New Jersey -						
Burlington	126,576	2	40,630	611	167,819	6
Camden	37,358	0	76,330	66	113,754	4
Gloucester	98,009	0	31,280	333	129,622	5
Mercer	94,053	0	45,900	105	140,058	5
Salem	55,817	0	9,316	204	65,337	2
Pennsylvania -						
Bucks	392,563	0	87,522	573	480,658	17
Chester	605,595	0	44,196	400	650,191	23
Delaware	77,740	0	103,356	19	181,115	6
Montgomery	455,270	0	106,488	809	562,567	20
Philadelphia	2,663	0	292,320	4	294,987	11
Totals	1,954,629	2	850,594	3,415	2,808,640	

[a]Based on MRI study.[1]

emission inventories is presented in Table 4 for the years 1969 through 1974. As may be seen from this table, a 38 percent reduction in total particulate emissions has occurred in Philadelphia during this period due to reductions in all source categories except transportation which increased 7 percent. A major share (56 percent) of this reduction is attributable to the decrease in emissions from power generation for which there was a decrease of 95 percent over the time period. This reduction is due to a changeover to residual and some distillate oil from use of residual and coal and the installation of control equipment at the four electric and two downtown steam generating stations in Philadelphia. In 1963, the electric generating plants in Philadelphia were supplied with 2 million tons of coal for 90 percent or more of their energy except at the Schuylkill plant which was 100 percent oil.[3] Between 1969 and 1971 the other three plants, operating with electrostatic precipitators, switched completely over to oil. Reductions in this source sector were particularly significant due to the fact that these were small power plants with relatively low stacks.

Reductions in emissions from the other major categories that may be considered point sources were not quite so substantial - 29 percent for industrial processes and 56 percent for refuse incineration. The change in emissions from industrial processes is felt to be due to stricter enforcement and some closing of industry. Since the control program for smoke and visible emissions had started 20 years prior, by 1969 many sources were already under some control with baghouses, electrostatic precipitators, scrubbers, etc. Emission reductions at major facilities that received special attention in reports to the Air Pollution Control Board between 1969 and 1973 are given in Table 5.

Emission reductions from refuse incineration occurred in steps with about half of the reduction attributable to a decrease in private incinerators between 1971 and 1972 and half due to control on municipal incinerators between 1973 and 1974. In 1969 to 1970, about 1,500 incinerators were in operation; by 1974 to 1975, there were fewer than 300. For the

Table 4. PARTICULATE EMISSIONS IN THE CITY OF PHILADELPHIA, 1969 TO 1974

Category	1969		1970		1971		1972		1973		1974		Change in emissions 1969-1974	
	TPY	%	TPY	%	TPY	%	TPY	%	TPY	%	TPY	%	TPY	%
Space heating														
Residential	8,930	14	9,110	17	8,370	19	8,400	20	7,600	19	7,900	20	-1,030	-12
Commercial	1,560	3	1,580	3	1,400	3	1,440	3	1,280	3	1,320	3	-240	-15
Governmental	1,150	2	1,180	2	1,080	3	1,110	3	990	3	1,020	3	-130	-11
Industrial	8,400	13	8,300	15	7,300	17	7,500	18	6,680	17	6,890	18	-1,510	-18
Subtotal	20,040	32	20,170	37	18,150	42	18,450	44	16,550	42	17,130	44	-2,910	-15
Power generation	14,440	23	7,200	13	1,020	2	830	2	820	2	750	2	-13,650	-95
Transportation[a]	6,230	10	6,320	12	6,410	15	6,500	16	6,540	16	6,650	17	+420	+7
Industrial process	16,800	26	14,300	27	11,900	27	11,700	28	11,700	29	11,900	30	-4,900	-29
Refuse incineration	5,900	9	5,900	11	5,900	14	4,200	10	4,200	11	2,600	7	-3,300	-56
Total	63,370	100	53,890	100	43,380	100	41,680	100	39,810	100	39,030	100	-24,340	-38

[a]Includes railroads, vessels, and aircraft.

Table 5. INDIVIDUAL INDUSTRY PARTICULATE EMISSIONS IN TONS PER DAY - 1969, 1973

Industry	1969	1973	% Reduction
Refinery	7.5	7.3	3
Coke	3.8	2.0	47
Refinery	3.0	2.5	17
Chemical	2.0	1.0	50
Smelting	2.0	0.5	75
Lead processing	1.5	0.1	93
Roofing materials	0.8	0.1	88
Chemical	0.6	0.3	50
Smelting	0.5	Closed	100
Totals	21.7	13.8	36

municipal incinerators, which had controls such as settling chambers and small spray scrubbing, two continuous incinerators are now having electrostatic precipitators installed and four batch incincerators are being closed and the waste hauled to landfills.

The least reductions in Table 4 are for those source categories that may be considered to be primarily area sources - space heating and transportation. While space heating had an overall reduction of 15 percent, inventoried transportation sources showed an increase of 7 percent, a result of increased vehicle miles traveled (VMT). This would indicate a combined reduction for these two source categories of only 9 percent, contributing 10 percent of the total reduced emissions level.

The decrease in space heating emissions may be considered to be attributed to two factors. First is the continued reduction in coal burned in Philadelphia. Table 6 provides a breakdown of the fuel usage between 1960 and 1973 for different source categories and utilizing different data inputs. Between 1960 and 1970, with a 4 percent increase in the total number of

Table 6. FUEL USAGE TRENDS IN PHILADELPHIA BETWEEN 1960 AND 1973 (DATA AS AVAILABLE)

	Residential usage (in number of dwelling units)			Industrial usage			Electric utilities		
	1960	1970	Ratio	1963	1972	Ratio	1964	1973	Ratio
Gas - 10^6 ft^3	218,590	368,942	1.69	77,234	93,400	1.21			
Oil - 1000 bbl	284,866	226,235	0.79	14,927	19,122	1.28	3,500	11,600	3.31
Coal - 1000 tons	100,024	20,513	0.21	1,330	190	0.14	1,982	0	0.00
Coke - 1000 tons				93	S				

Note: S - data not statistically significant.

dwelling units, the use of oil and coal decreased 21 percent each while the use of gas increased 69 percent. The total amount of coal consumed by industrial users decreased 86 percent between 1963 and 1972. Currently only 20,000 tons of coal are being consumed each year by domestic users, emitting 100 tons per year of particulates. By 1974, no coal was being consumed by industrial or commercial users and, in the governmental sector, three state hospitals and 111 public schools under compliance schedules were burning coal.

The other factor that would influence space heating loads over the years would be changes in heating load requirements. Figure 8 provides a plot of how the degree days and space heating emissions have fluctuated over the past 6 years. From this figure, it is evident that a major share of the reduction in space heating emissions would be directly attributable to the 10 percent decrease in heating degree days, especially for the non-industrial sources. With some years having more than 20 percent more heating degree days than in 1974, as much as a 10 percent increase in total yearly emissions (a greater increase on a seasonal basis) could easily result.

Given this correlation between space heating emissions and heating degree days, an estimate of the seasonal fluctuations in emissions can be made by apportioning the space heating emissions to the various months of the year based on the degree days in each month; this is done in Table 7 for 1974. From this table, it would appear that in Philadelphia, there are two to three times the emissions in the winter months then in the summer months, and therefore, one would expect the air quality to be much worse during this time. Figure 9 provides a plot of the ratio of the total monthly emissions to the average monthly emissions and also the citywide TSP monthly geometric means in 1974. While the concentration does go up in the winter months, it also rises in the summer months. Other factors, such as meteorology, must also be influencing the air quality in these months. These are discussed later in this section.

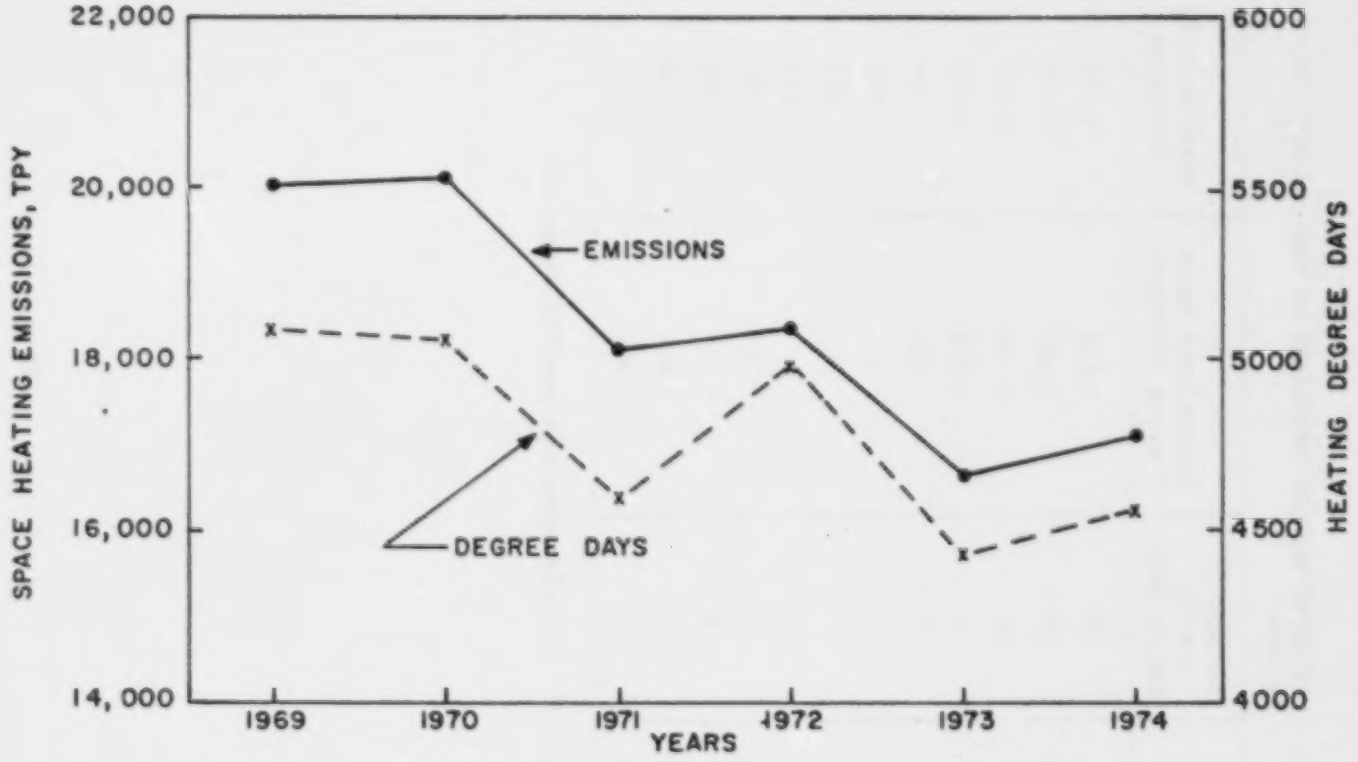


Figure 8. Emissions from space heating and degree days in Philadelphia, 1969 to 1974

Table 7. ESTIMATED MONTHLY EMISSIONS OF PARTICULATES IN PHILADELPHIA IN 1974

Month	Percent of yearly degree days	Apportioned space heating emissions	Total monthly emissions	Ratio[a]
January	20	3,426	5,251	1.61
February	20	3,426	5,251	1.61
March	15	2,570	4,395	1.35
April	6	1,028	2,853	0.81
May	3	514	2,339	0.72
June	-	-	1,825	0.56
July	-	-	1,825	0.56
August	-	-	1,825	0.56
September	1	171	1,996	0.61
October	7	1,199	3,024	0.93
November	11	1,884	3,709	1.14
December	17	2,912	4,737	1.46

[a]Total monthly emissions/average monthly emissions.

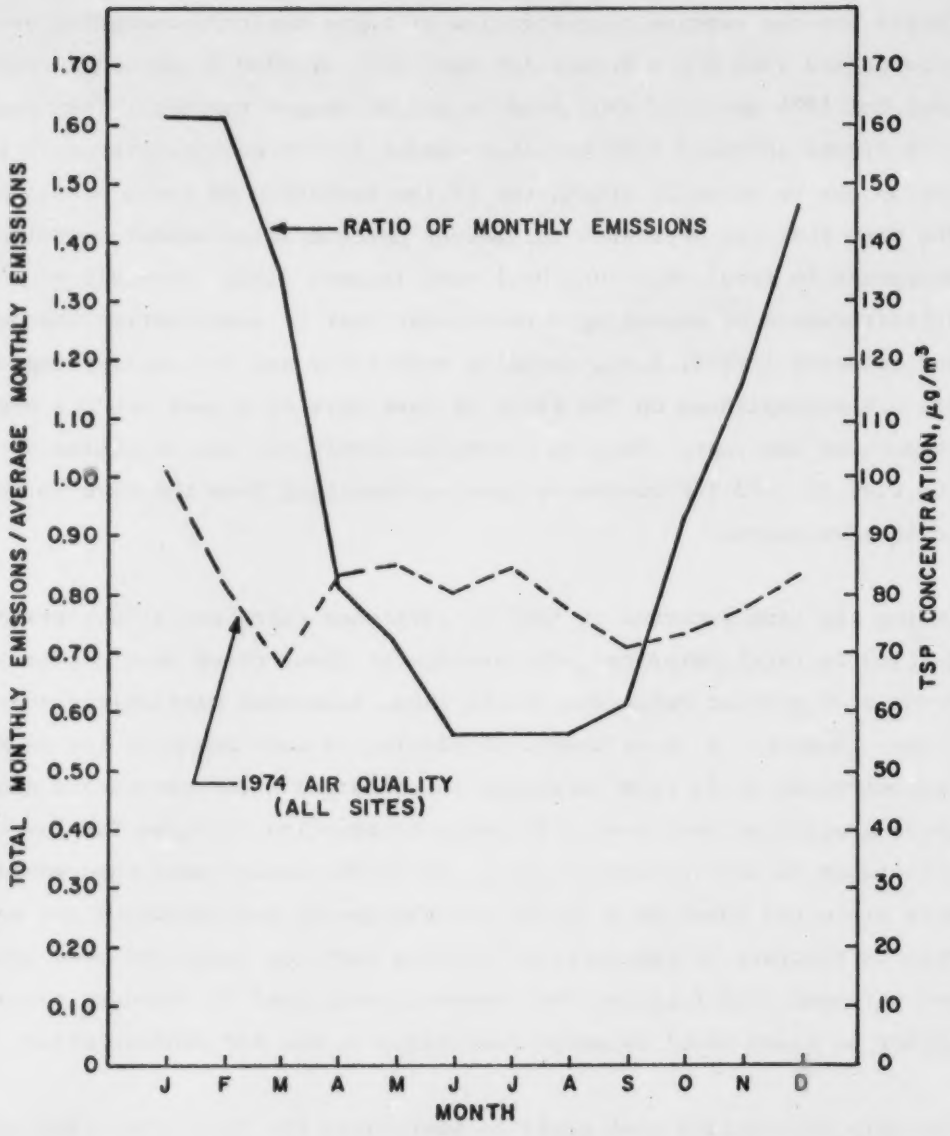


Figure 9. Monthly emission ratio and TSP concentration in Philadelphia in 1974

To determine how the changes in emissions have affected the air quality over the longer period, and which categories have the most direct correlation with TSP concentration, the emissions from each source category, the total emissions (divided by three to fit on the graph), and the ambient TSP levels for 1969 through 1975 are plotted in Figure 10. The ambient TSP levels are the average concentration of three monitors operating over that time period (500 South Broad, AMS Lab, NASN at 3200 Frankford Avenue) except for 1974 when the NASN monitor was no longer running. The trends in this figure indicate that the improvement in air quality over this time period can be directly attributed to the reduction in total emissions. The fact that the decreases in ambient concentration appear to follow the decreases in total emissions by 1 year is most likely a result of the definitiveness of selecting a particular year to characterize the ambient and emission levels; i.e., emission reductions and air quality improvements are not accomplished on the first or last days of a year but are ongoing throughout the year. Such an assumption could provide an explanation for the rise in 1973 TSP concentrations as resulting from the rise in space-heating emissions.

During the time interval of 1969 to 1974 when there was a 38 percent reduction in total emissions, the average of these three stations indicated about a 30 percent reduction in the total suspended particulate concentrations. However, if a rollback calculation is made assuming the background concentration of 35 $\mu g/m^3$ utilized in the state's implementation plan, there appears to have been a 45 percent reduction in those TSP levels attributable to city activity; i.e., almost 20 percent more than would have been projected based on a direct correlation of concentration and emissions. This is contrary to the expected finding that the impact of area sources and uninventoried fugitive dust sources would tend to discount the actual impact of known total emission reductions on the TSP concentration.

The only explanation that could be postulated for this other than expected finding is that the actual locations of the monitors, while not being source oriented, are more heavily influenced by emissions from those

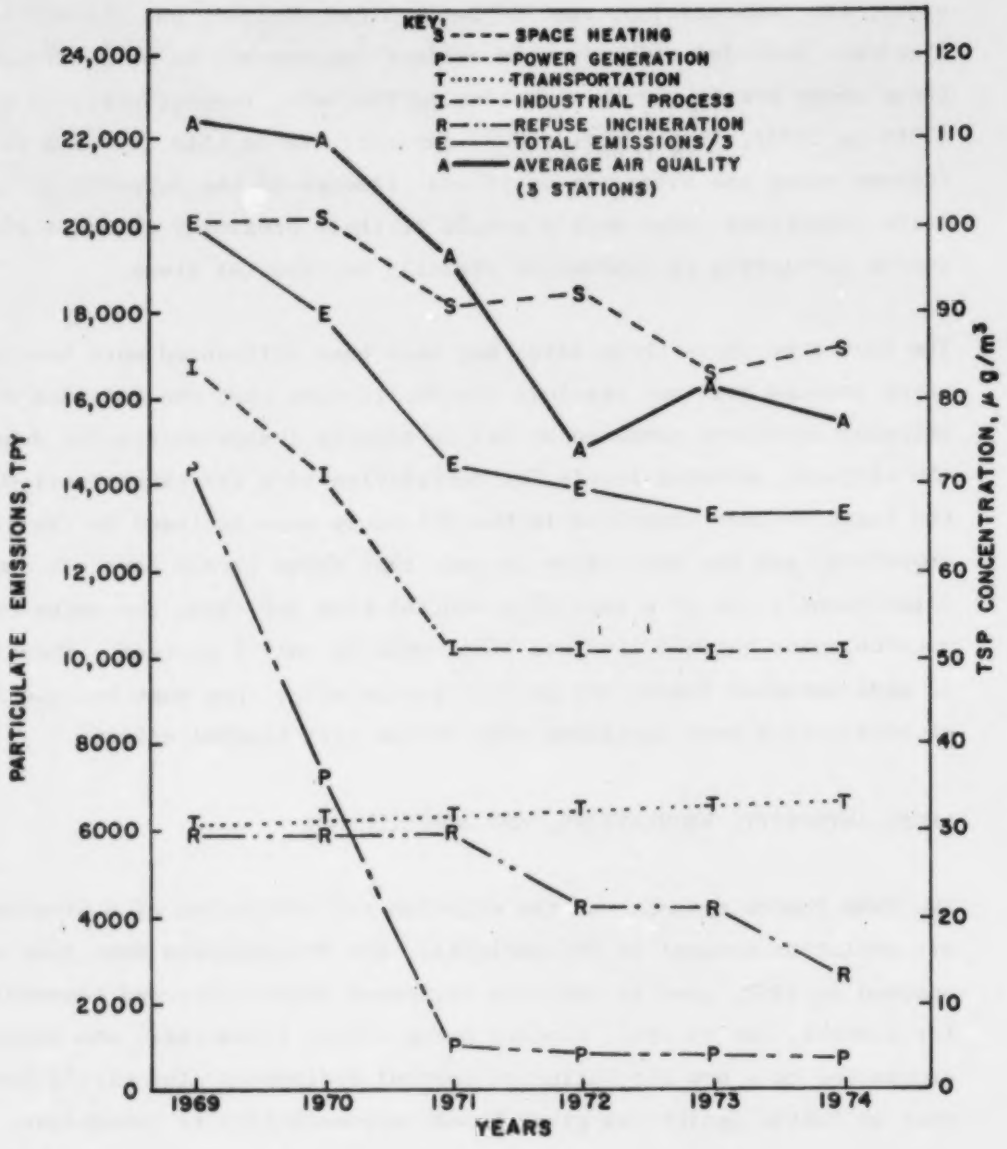


Figure 10. Particulate emissions and ambient concentration in Philadelphia, 1969 to 1974

source categories that have had the greatest reductions over the past 6 years; i.e., power plants, industrial sources, and incineration. The order in which the monitors could be considered to be most heavily influenced by these sources based on the surrounding neighborhood would be, in descending order, the NASN station, the 500 South Broad station, and the AMS lab station. Recorded reductions in ambient concentrations of particulates at these three stations over this time period were, respectively, 43 percent (1969 to 1973), 41 percent, and 37 percent. While this is not a large difference among the sites, it would add credence to the supposition that the large reductions noted were a result of their proximity to the individual source categories as opposed to strictly residential areas.

The fact that these three sites may have been influenced more heavily by major sources does not preclude the implication that the fugitive source emission inventory prepared by MRI is totally inappropriate for describing the citywide emission levels for correlation with TSP concentration. If the fugitive dust emissions in the MRI study were included in the total inventory, and the assumption is made that these levels have not changed significantly due to a lack of a control plan for them, the emission reduction noted between 1969 and 1974 would be only 7 percent. Therefore, if such emission levels are present in the city, they must be considered to have only a very localized (one to two city blocks) effect.

LEGAL AUTHORITY, REGULATIONS, AND SURVEILLANCE

The 1948 Donora episode was the stimulus for initiation of a program of air pollution control in Philadelphia. The Philadelphia Home Rule Charter, adopted in 1952, gave to the city increased opportunity and responsibility for control, and by 1954, concern among civic, industrial, and business groups led to a new Air Pollution Control Ordinance. The city's Department of Public Health was given broad responsibility to investigate complaints, to abate nuisances and hazards, and to examine plans and specifications for new or remodeled equipment considered to be potential

pollution sources. The ordinance was followed by a series of specific regulations for control of a number of air pollution problems.

In the summer of 1968, the Air Pollution Control Section of the Department of Public Health was replaced by the Air Management Services, a separate component of the Department headed by an Assistant Health Commissioner. The Service derives its authority from the Federal Clean Air Act, Pennsylvania's Air Pollution Control Act, Philadelphia's Home Rule Charter, the Air Management Code, and the Regulations of the Air Pollution Control Board.

There are currently 10 regulations promulgated by the Air Pollution Control Board which relate to the control of air quality in the City of Philadelphia. These regulations include the normal control measures for air pollution episodes, permit and license review, and complex source review; the control of emissions of sulfur oxides, organic substances, nitrogen oxides, and carbon monoxide (one regulation each); and the control of particulate emissions (three regulations). In addition, the Air Management Code bans open burning and controls sulfur content in fuel. The regulations which directly control the emission of particulate matter are summarized below.

Regulation II - Air Contaminant and Particulate Matter Emissions (adopted April 10, 1970 and subsequently amended). This regulation reiterates and amplifies the open burning ban to include fire prevention measures in salvage areas, requires approval for the discharge of toxic or radioactive air contaminants, and prohibits visible emissions darker than No. 3 on the Ringelmann Chart or darker than No. 1 for more than 3 minutes in any 1 hour. Particulate matter from fuel burning may not exceed 0.2 lbs per 1,000 lbs of stack gas for existing units and 0.1 lbs per 1,000 lbs for new (after 1970) units; process emissions are limited to those given in Figure 11; and fugitive dust is regulated by requiring "measures to prevent air contamination."

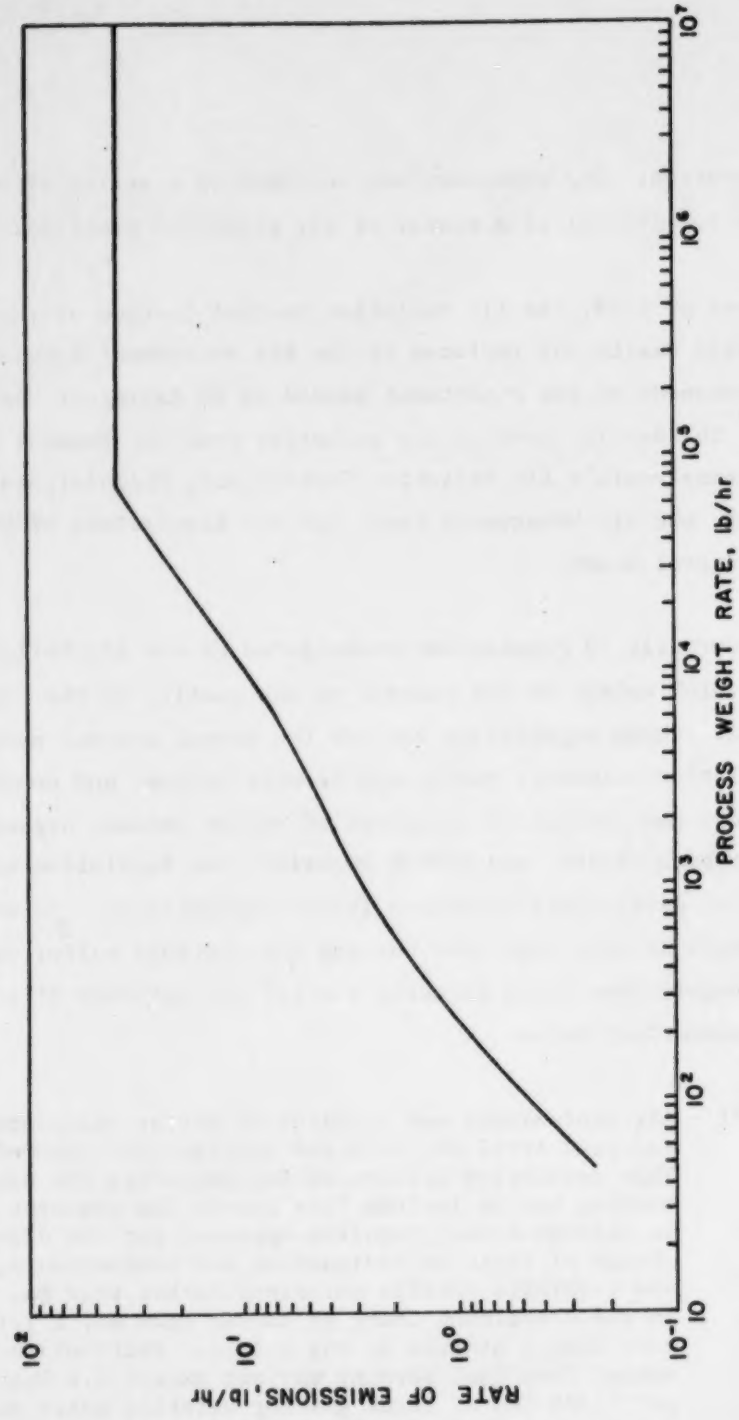


Figure 11. Process weight rate curve for the City of Philadelphia

Regulation IX - Control of Visible Emissions from Mobile Sources (adopted July 18, 1972). The emission of visible air contaminants in excess of 20 percent opacity is prohibited at all times and any visible emissions except for 3 consecutive seconds after starting for gasoline and diesel powered motor vehicles and for 5 consecutive seconds while in motion for diesel powered vehicles are prohibited under this regulation.

Regulation XI - Control of Emissions from Incinerators (adopted March 12, 1974). This regulation prohibits the installation of any new incinerator with a burning rate less than 10,000 lb per hour, the emission of particulate matter at a rate in excess of 0.08 and 0.10 grains per standard cubic foot for new and existing incinerators, respectively, and visible emissions equal to or greater than 20 percent opacity for more than 30 seconds in an hour or 3 minutes in 1 day with a maximum 60 percent opacity. The gases from incinerators are also controlled to prevent odorous emissions.

In addition to these regulations promulgated by the Air Pollution Control Board, the regulations imposed by the Pennsylvania Environmental Quality Board for the control of emissions are also applicable in the City of Philadelphia. Enforcement is based on which of the regulations is the most stringent for the individual source; e.g., process sources have to meet both the city's process weight rate and the Commonwealth's grain loading requirements. A discussion of how these regulations compare with those in the City of Philadelphia is given below for each source category.

The regulations of the Pennsylvania Environmental Quality Board for fugitive emissions are more specific on control than those imposed by the Philadelphia Air Pollution Control Board. While both Boards require all reasonable measures to prevent particulate matter from becoming airborne and could therefore be interpreted for stringent control, the Environmental Quality Board also prohibits the transport of particulates past the property line if they are visible or exceed 150 particles per cubic centimeter above the background level.

The control of emissions from combustion units would have to be a combination of the two sets of regulations. The Philadelphia regulations use a weight per 1,000 lbs of stack gas rate and the Commonwealth uses a weight per million Btu input (0.4 lbs/10^6 Btu if $2.5 \leq E < 50$; 3.6 $E^{-0.56}$ lbs/10^6 Btu if $50 \leq E < 600$; 0.1 lbs/10^6 Btu if $E \geq 600$; where E = heat input in millions of Btu's per hour). Assuming a normal flow rate of 1,000 lbs flue gas per million Btu heat input, existing combustion units would be controlled by the Philadelphia regulation up to about 175 million Btu's whereafter they would be controlled by the Pennsylvania regulation. All new sources would be operated entirely under the city's regulation.

Emissions from processes are regulated by different techniques by the city and Commonwealth. While the city has a general process weight rate regulation the Commonwealth sets a general maximum rate of grain loading (0.04 grains/scf if $V < 150,000$; 6,000 V^{-1} grains/scf if $150,000 \leq V < 300,000$; 0.02 grains/scf if $V > 300,000$; where V is the effluent gas volume in dry standard cubic feet per minute). In addition, Pennsylvania has adopted specific process weight rate regulations for 30 different major processes using tons of product or specific feeds for determining the allowable emissions. No easy comparison can be made between these two sets of regulations and testing for compliance is done on the basis of both sets of regulations.

The Commonwealth's regulation for emissions from incinerators are equal to or less stringent (for new incinerators) than those imposed by Philadelphia so the city's regulation would be the only one used for control. Similarly, the regulations for visible emissions are equivalently stringent at both the city and the Commonwealth level.

A preliminary analysis of the Philadelphia regulations, utilizing published studies and the cities reviewed to date, determined that the control of particulate emissions in Philadelphia was about average in terms of relative stringency. The allowable emissions from fuel combustion are as

stringent or more stringent than the regulations in most areas around the country.[2] Specifically, they are more stringent than in three areas studied to date (Providence, Birmingham, and Denver) and an order of magnitude less stringent than the severe regulations promulgated in Baltimore. The general process weight rate is more stringent than those in the other areas reviewed for most process feeds but is equal to or only slightly more stringent than the average of all state regulations applicable to general process sources.[3]

Determination of compliance with these regulations is most often done by checking out the equipment and the use of theoretical calculations. About 10 source tests for particulates per year are conducted by AMS and not that many more are done by consultants. A lot more effort recently is going into the control of organics so this may be hurting the enforcement for particulates. Continued compliance determination is done on a visual basis with an engineering inspection for all sources at least once a year for licensing purposes. Large sources are visited several times each year by inspectors as well as on a by-complaint basis. In the last year, there were an estimated 170 municipal court cases, 3,400 visits by inspectors, 6,300 opacity observations, and 1,500 in-plant engineering inspections. It was estimated that only a very small percentage of the sources were not in compliance (5 to 10 percent of the tons per year). Overall, the enforcement function of AMS was determined to be "quite successful in providing an effective source surveillance and compliance program in the city."[4] However, a slippage in the expected output in the areas of source inspection and licensing for 1974 were considered to be "much less than desireable or...required for these activities."[4]

NETWORK DESIGN

Because of the widespread nature of the AQCR and the multitude of responsibile agencies that would be involved, no analysis of the monitoring network for the whole AQCR was attempted. Instead, attention was directed at the monitoring network operated by AMS in the City of Phiadelphia. This network was found to be fairly well designed in terms of neighborhood selection and monitor siting with the exceptions noted below. The primary deficiency appeared to be the lack of a monitor located at a nonsource specific site in the center of major industrial activity.

The monitoring sites operating in the City of Philadelphia during 1974 are grouped in Table 8 according to the predominant characteristic of the neighborhood of each. This table also provides the geometric mean for each station and summarizes the siting comments from field visits. Four stations were operating in residential areas; three were in the center city; and five stations were in areas of industrial activity. The locations of these stations were given in Figure 2.

The residential areas of the city appear to be adequately represented by the 1974 monitoring network with the possible exception of the southwest portion of the city away from the Philadelphia International Airport, not a major problem but of interest because of the predominant southwest winds. More importantly, the closing of the Belmont Filter Station monitor in November 1974 leaves no really well-located station for the sampling of particulates coming into the city. The Roxborough monitor is too far to the northwest of the city to represent incoming air masses and also is poorly sited with respect to the southwest exposure due to an approximately 50 foot tree within 10 feet of the monitor. The other residential area monitors appear to be reasonably sited. The average mean at these four stations was 68 $\mu g/m^3$ in 1974.

Table 8. ANALYSIS OF 1974 TSP MONITORING SITES IN PHILADELPHIA

Neighborhood	AMS #	Location	1974 TSP annual geometric mean	Siting comments
Residential	4	Belmont Filter Station	72[a]	Open area of reservoir and park, traffic only source,
	5	Roxborough Filter Station	59	Open area, large tree to S.W. within 10 feet
	6	Northeast Airport	64	Open area, possible influence from airport to east
	9	AMS Lab	78	Densely settled, heavy traffic
Center City	8	Franklin Institute (CAMP)	119	Close to dirt parking lot, traffic influence
	10	South Broad and Spruce	115[b]	Close to paved parking lot, traffic influence
	12	500 South Broad	76	Highest monitor site (4 stories), 100 feet from street
Industrial	1	Defense Supply Depot	105	Located in depot, influence from railroad traffic
	2	Allegheny Ave. & Delaware River	122	Open area, near river, dirt roads, grain elevator to west
	3	International Airport	94	Open area, tree to north touching site
	11	S.E. Water Pollution Control	78	On ground, against building, between shrubs
	13	Aramingo Fire Station	116[c]	Source specific to west, parapets 3 feet above hi-vol

[a] Station closed 11/20/74.

[b] First sample 9/8/74.

[c] First sample 11/1/74.

The center city area is quite well monitored, especially with the addition of the North Broad station at the end of 1974, and all of the monitors received adequate ventilation. The monitor at 500 South Broad is the highest monitor in the network but is only about 35 feet off the ground. However, this height, coupled with its distance of about 100 feet back from the major road (South Broad) does provide for lower readings than the station two blocks away at South Broad and Spruce which is 13 feet off the ground and approximately 20 feet back from South Broad Street. A comparison of 12 pairs of concurrent observations made during the months of September through December 1974 at these two sites showed that in every case, the concentration at 500 South Broad was substantially below that measured at the intersection of Broad and Spruce. The geometric means at these two stations for this time period was 65 and 115 $\mu g/m^3$, respectively. Assuming a background level of 35 $\mu g/m^3$, the Broad and Spruce station would be considered to be influenced almost three times as much by the city's activity than the station at 500 South Broad. This discrepancy raises questions as to the appropriateness of the monitor siting and the use of the lower value from 500 South Broad, the only high station in the network, in the calculation of a citywide average.

The other downtown area monitor is located about eight blocks northwest of the center of the city on the grounds of the Franklin Institute and also serves as a CAMP station. This station is located near a dirt and gravel parking area which could have a major impact on the measured TSP levels given the right meteorological and local activity conditions. These conditions at the CAMP station, along with these of the monitors on South Broad, are investigated further in the analysis of urban activity.

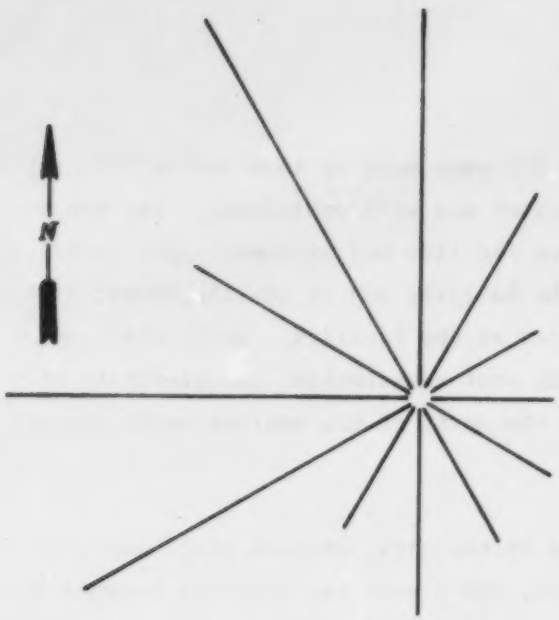
Although there are five monitors located in neighborhoods that have industrial activity, none of the monitors were felt to really represent the air quality in the midst of an industrial area. Through conversations with the AMS personnel, the feeling was given that the monitor at the Defense Supply Depot might be more influenced by the activity in the Depot than outside activities. The other two monitors in that portion of

the city (No. 3 and No. 11) were more or less remote from any industrial activity and neither monitor was well positioned. The monitor at the Southeast Water Pollution facility had extremely poor ventilation due to its placement against the building and in the shrubbery; it has since been moved to an open area at the facility. While the sampler at the airport was not receiving poor ventilation, the proximity of a large (about 40 feet) tree to the north of the monitor would disrupt air flow from that direction.

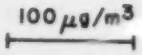
In the northeast portion of the city, where a large amount of industrial activity was also present, there were two monitors located in the industrial area. One the the monitors (Aramingo Fire Station) was obviously source specific for National Lead located across the street but the ventilation for the sampler was poor due to the high parapets (about 3 feet above top of the hi-vol) surrounding the monitor on the roof. Figure 12 provides a pollutant rose of the data collected to date and Aramingo Fire Station and a pollutant rose at a more remote station during the same time period. This figure indicates greater than expected concentrations in the direction of the National Lead Plant (north to southwest). The other site, at the end of Allegheny Avenue by the Delaware River, had good ventilation but was remote from any industrial activity except for the grain elevator to the west of the monitoring site. A dirt road and gravel piles to the west of the site were other obvious potential influences.

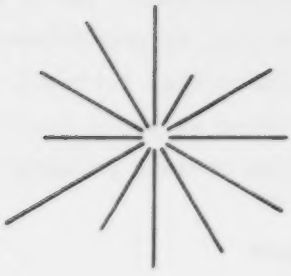
METEOROLOGY AND CLIMATOLOGY

The general meteorology of the area appears to be one of the factors prominent in determining the TSP levels in Philadelphia. Numerous meteorological parameters were investigated for Philadelphia including the yearly and monthly variations in precipitation and space heating demands (degree-days), the average windspeed and number of days of precipitation each month, and the macroscale movement of air masses through the use of a precipitation rose. In addition, some conclusions from a study of daily rainfall by the Philadelphia Air Management Services Laboratory are



(a) Aramingo Fire Station





(b) Roof of Franklin Institute

Figure 12. Pollutant rose comparison for source oriented monitor (Aramingo Fire Station)

included in the analysis. Supporting data on meteorological parameters considered below is given in the appendix.

Precipitation is normally considered to be the meteorological parameter which has the maximum impact on air quality levels, aside from ventilation rate. It helps to clean the air of particulates through washout and rainout and can suppress the rise of pollution levels by wetting down particulates that would be resuspended if dry or even washing particulates off the streets into sewer systems if the rain is heavy enough. The expected relationship is one of inverse correlation with the pollutant concentration.

Figure 13 provides an inverse graph of the precipitation over the past 18 years by dividing the normal (1947 to 1970) precipitation level by that which occurred in each of the years. Overlayed on this figure are the annual geometric means for particulates measured at the NASN station at 3200 Frankford Avenue and at the city-operated station at 500 South Broad Street. These stations have the longest period of record during this time but were not the only stations operating (see air quality discussion). The NASN station was operated on a random day basis while the South Broad station was operated on a daily basis until 1973 when no samples were run on Sunday or Monday. The degree to which the inverse precipitation graph and the air quality levels rise and fall together provides an indication of the correlation of the two parameters. From this figure, it is apparent that the precipitation in Philadelphia could be having some impact on the annual geometric means reported for these two stations, but to varying degrees. With the principal exception of 1968, the changes in air quality levels measured at the NASN station appear to correlate quite well with the rising and falling of the inverse precipitation graph. The correlation is much better for the NASN station that only ran about 25 filters each year than for the South Broad site, which was run almost daily. The improvement in air quality seen at this site starting in 1965, which could be interpreted as following the trend in precipitation, would probably be more attributable to the changes in emissions during this time period.

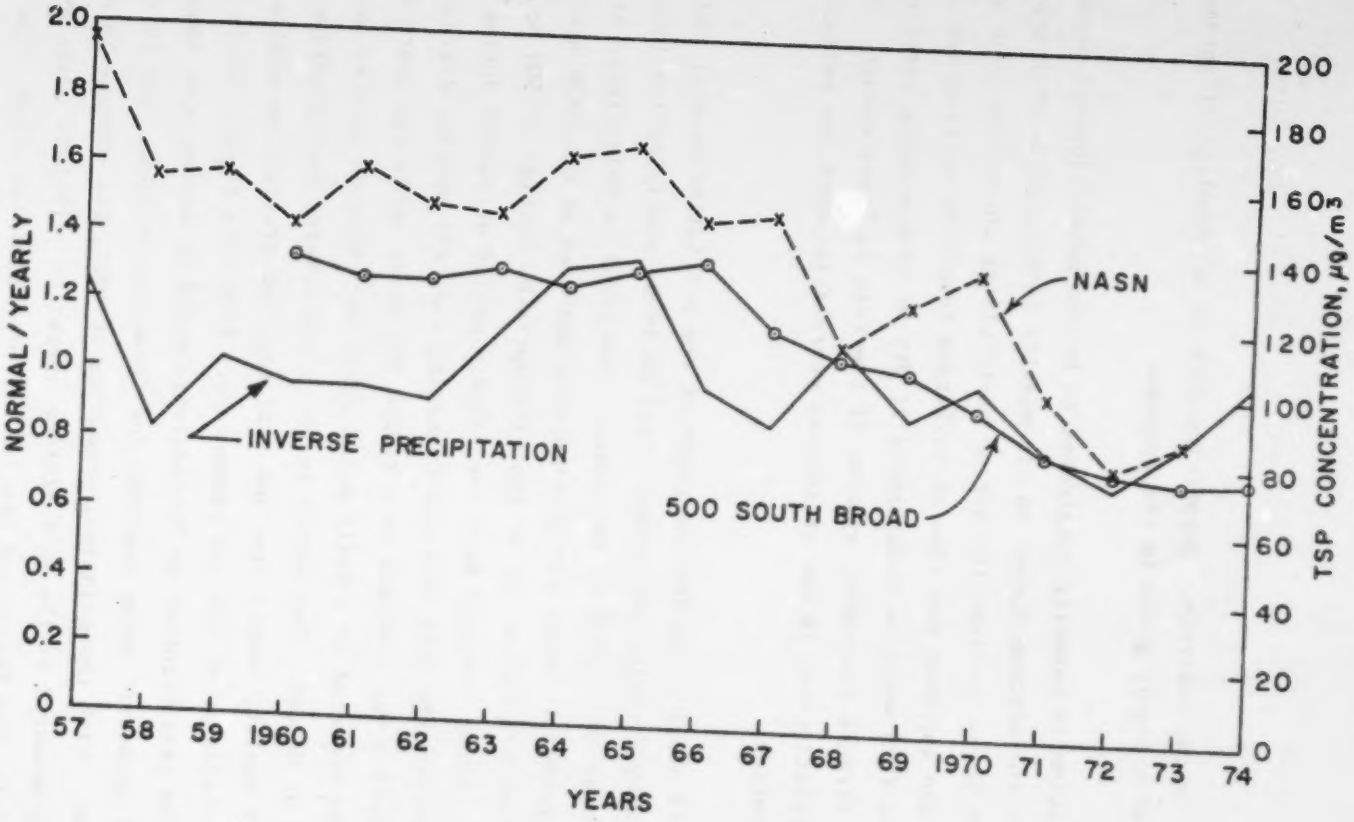


Figure 13. Normal/yearly precipitation and TSP air quality levels in Philadelphia, 1957 to 1974

A better way of determining the relationship between precipitation and air quality levels is to consider a citywide average of air quality, thereby discounting major influences that certain activities may have on an individual site. Such an analysis was performed utilizing 1974 data and monthly fluctuations over the year. A major advantage of this 1-year analysis is that wider fluctuations in the meteorology are expected on the smaller time scale and these wider fluctuations should be reflected in the air quality levels if there is a correlation. While one problem of changes in emissions over long time scales is eliminated, the additional problem of seasonal fluctuations in the emission levels is present.

Again in the interest of normalizing the rainfall levels and wanting to show comparable changes in precipitation and air quality, Figure 14 provides a graph of the average monthly geometric mean for all monitors in Philadelphia along with the normalized inverse of monthly precipitation (average monthly/monthly). From this graph, it is evident that, with the exceptions of January and December, the inverse precipitation and the air quality plots correlate reasonably well. Several reasons may be postulated for the lack of tracking in January and December. First, as discussed earlier under the emissions analysis the increased heating load in the winter months would indicate more emissions, perhaps outweighing the benefits from precipitation. In addition, the snowfall that is expected to be a major form of the precipitation in these months may not have the cleaning effects of actual rainfall.

In January, there was one major snowfall of 3.7 inches and a couple of small snowfalls of 0.2 inches each. On the day of the major snowfall, citywide levels (three monitors sampling on that day) were 12 percent lower than the levels sampled the days before and after. On one of the days of light snow, the level was 90 percent higher than the previous day and 11 percent lower than the following day at the one monitor that was sampling all three days. On the other light snowfall day, however, the ambient levels measured at the two operating stations were about 40 percent lower than the levels measured the days before and after. On this latter day, the notations on the weather conditions indicate that rain

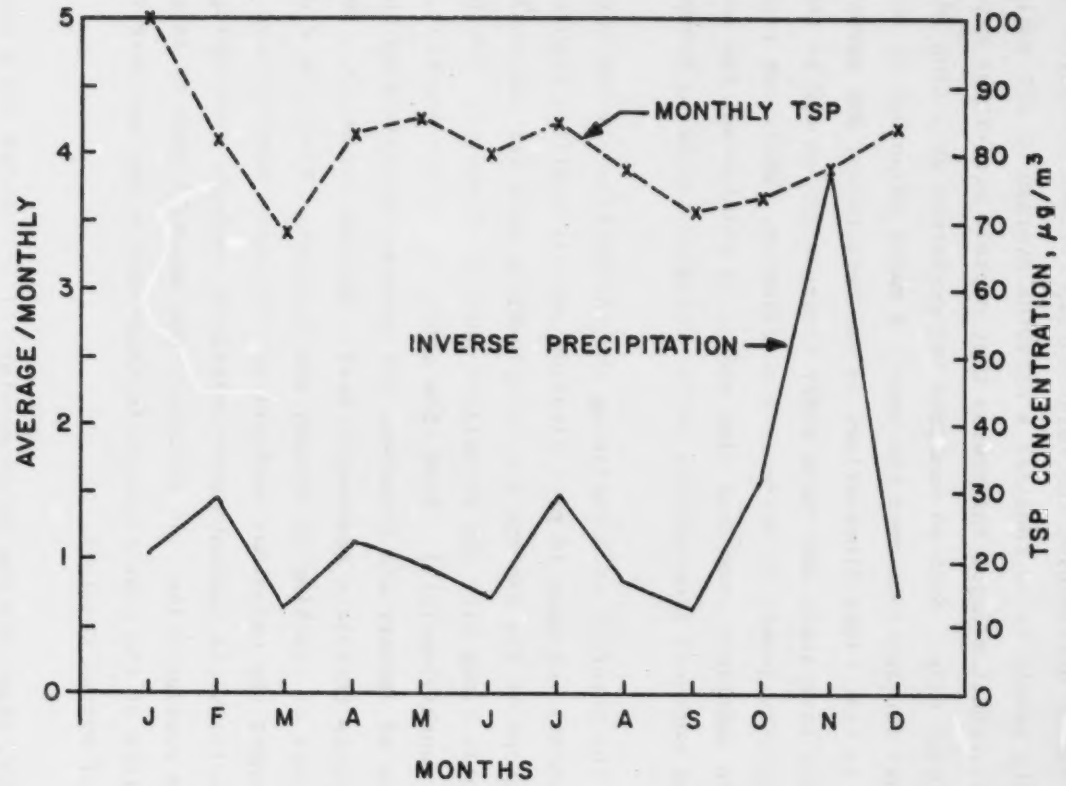

AVERAGE/MONTHLY
TSP CONCENTRATION, µg/m³
MONTHLY TSP
INVERSE PRECIPITATION
MONTHS
J F M A M J J A S O N D
0 1 2 3 4 5
0 10 20 30 40 50 60 70 80 90 100

Figure 14. Average monthly/monthly precipitation and citywide monthly geometric means for TSP in Philadelphia, 1974

and ice pellets were actually more prevalent than snow which may be the reason for this greater decrease in ambient levels. If one were to discount the snowfall as having less effect on the TSP levels then rainfall, the inverse normal plot of precipitation in January given in Figure 14 would have better correlated with the rise in TSP levels for that month.

In December, on the other hand, a similar explanation cannot be found. The high level of precipitation for this month was due entirely to rainfall except for 0.31 inches from a snowfall on December 31. This amount of precipitation is insufficient to make any major changes in the inverse precipitation plot for December and would also not be that appropriate as the snowfall came in the last 10 hours of the month. In addition, it can be noted that the pattern of precipitation was not significantly different in the month of December; in fact, there were the same number of days of precipitation in December as in November, a month with only one-fifth as much rainfall as December but lower TSP levels. In general, throughout the year no obvious direct correlation was found between number of days of precipitation and the TSP levels.

A preliminary, simple statistical analysis of suspended particulate levels and periods after heavy rainfalls was conducted by Clemens Lazenka and Thomas Weir of the Philadelphia Air Management Services.[5] Particulate levels in 1972 and 1973 from three stations (500 South Broad Street, AMS Lab, and Southeast water treatment plant) measured for the day after rain, the second day after rain, and the third day after rain were compared with those measured the seventh day after rain. Days of rain had to have at least 0.25 inches of rain during the day or a rate of 0.1 inches or more in 1 hour. Other parameters such as wind direction and speed were matched. The study concluded that, after periods of heavy rain, particulate levels were significantly reduced on the first day (95 percent confidence) and the second day (90 percent confidence) when compared with the seventh day after rain but that, by the third day after rain, no significant difference was found. Figure 15 presents a graphical representation of these results.

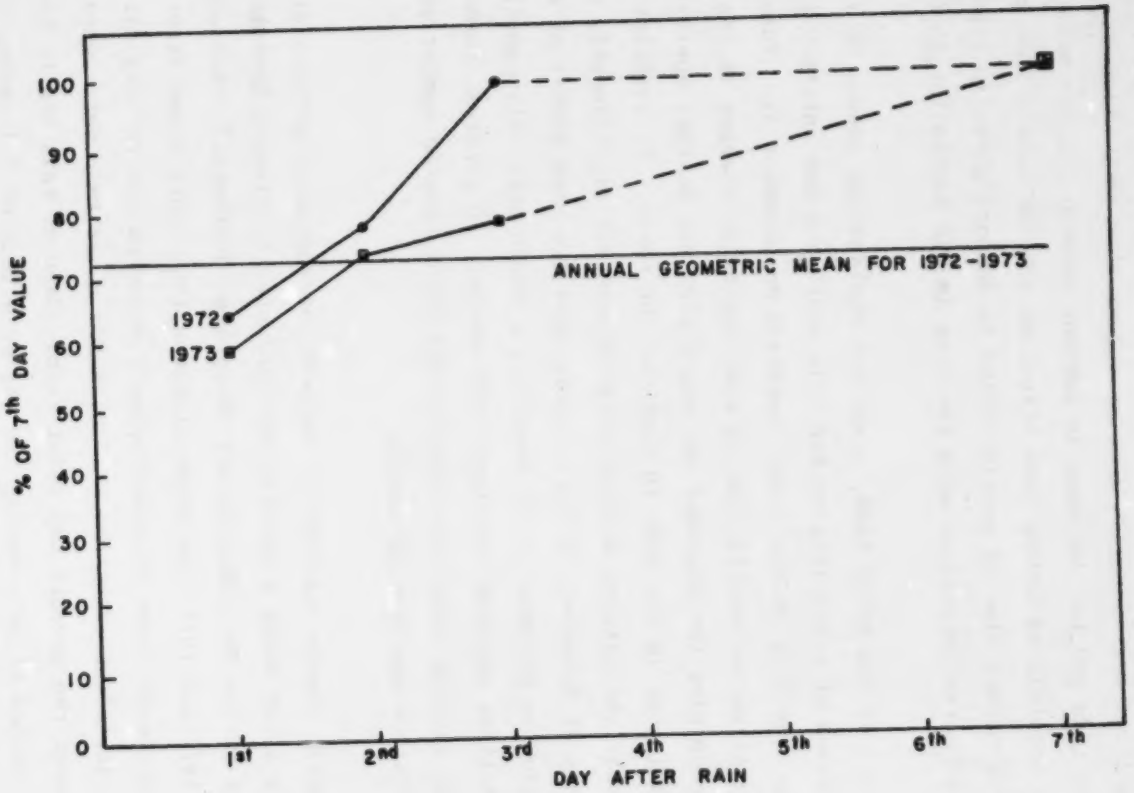
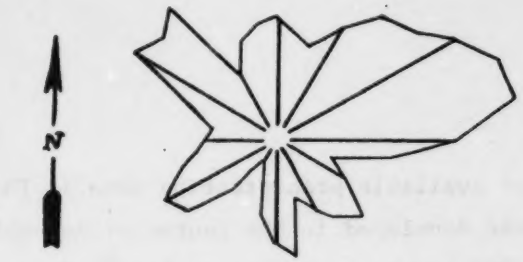


Figure 15. Measured TSP levels after rainfall (as compared to 7 days after rain)

The other review of available precipitation data in Philadelphia concerned a precipitation rose developed in the course of an analysis of construction activity and TSP levels performed by EPA.[6] This precipitation rose, a plot of precipitation levels and corresponding wind direction, indicates that the major rainfall occurs with winds from the east to northeast direction (see Figure 16). About twice as much precipitation occurs with winds from these directions than from all other directions except the northwest area which has about 75 percent as much rain as the ENE winds. The least amount of precipitation occurs with winds from the southwesterly direction. This precipitation pattern corresponds with the general flow of air masses of dry Bermuda Highs with southwesterly winds, cold fronts with northwesterly winds, and northeasterly storms. Figure 16 also includes pollutant roses for the two well situated residential, low source oriented monitors (Northeast Airport and Belmont Filter Station). A comparison of these roses provides the expected relationship that the direction of the most rain also has the lowest TSP levels, and vice versa.

The analysis of the space heating emissions and the heating degree days presented under the discussion of emissions indicated that a correlation between these two parameters did exist. Further, the assumption of the correlation provided a seasonal emissions pattern by distributing the yearly space heating emissions to each month based on the number of degree days in each month. This seasonal emission pattern is then useful for explaining the rise in TSP concentrations during January and December when the precipitation pattern would imply a downturn.

The other meteorological parameter investigated in Philadelphia - windspeed - showed no obvious direct correlation with the measured TSP levels. It is expected that, while this parameter does have an impact on the ambient concentration, interference from more significantly related factors preclude the immediate determination of any correlation. The analyses indicated that the TSP level appeared to be inversely related to windspeed during the first half of 1974 but directly correlated the second half.



(a) Precipitation Rose

(b) Pollutant Roses

Figure 16. Precipitation and pollutant roses in Philadelphia

URBAN ACTIVITY

Several elements of urban activity were investigated in the course of study to determine how these activities impacted on the measured ambient air quality. The two major areas of analysis were construction activity and traffic related emissions.

Construction

Construction activity was thought to be a possibly prominent source of particulates due to the calculated emissions from the MRI study[1] which indicated that the tons per year from this source category were seven times the total amount inventories by the City of Philadelphia. During the course of this study, a review of construction and demolition activity and measured ambient levels of TSP was conducted by EPA.[6] This review included analyses at several levels of the data - citywide, administrative area, and at specific monitoring sites.

The citywide and administrative areawide analyses in this study showed no definitive correlation between construction activity and measured TSP concentrations. This is in agreement with the analysis of emission trends presented earlier in this section whereby air quality improvements were better correlated with the decrease in traditionally inventoried emissions then with construction activity added into the emission inventory.

The possibility that individual monitoring sites are influenced by the nearby construction activity was investigated through the analysis of six specific monitoring sites. Pollutant roses were utilized to identify greater than expected contributions from the direction of construction activity within one mile of the monitoring site. The results of this analysis indicated some probability that construction activity will affect the measured air quality levels but the data presented was not detailed enough to determine the statistical significance of these results. The information provided in the study appeared to preclude any wide-scale

impact of construction activity but rather that any impact would be of a very localized nature.

In addition to a review of the above analyses, a cursory analysis of a remark regarding nearby demolition on a NASN reporting form was conducted. The remark indicate that demolition of a three story building was taking place 50 yards from the hi-vol sampler at the CAMP stations. The day had light winds, primarily from the north to west direction, and no precipitation. Unfortunately, no comments were made as to the direction of the demolition activity. The values measured by both the NASN sampler (99 $\mu g/m^3$) and the AMS operated sampler at the same site (107 $\mu g/m^3$) indicated no substantial increase in the ambient particulate levels and, in fact, the levels were lower than the annual geometric means of 109 and 119 $\mu g/m^3$, respectively.

Traffic Activity

A couple of studies[7,8] in Philadelphia have implicated motor vehicles as major contributors to the measured TSP concentrations with contributors as high as 90 percent. The indication is that monitors situated close to the roadway will be more influenced by the passing traffic than by higher point source emissions and that inventoried mobile source emissions do not fully represent the contribution from this source sector. Several analyses of the possible influence of traffic on the ambient air quality in Philadelphia were conducted to attempt to provide further insight into this question.

Two sets of comparably located monitors provided data for comparison of the impact of height from the ground. Much of this data for the paired monitors on South Broad Street has already been presented in the discussion of the monitoring network design. At these monitors it was found that the above background level of the station 13 feet of the ground and 20 feet back from the road (a slant distance of 24 feet) (S. Broad & Spruce) was almost 3 times higher than for the station 38 feet

above the ground and 100 feet back from the road (a slant distance of 107 feet). The traffic levels near each of these sites are fairly close, at about 30,000 vehicles per weekday for each.

One other difference in siting of these two monitors, aside from the slant distance from the road, is the position of the monitor with respect to the major road under consideration, South Broad. The monitor at South Broad and Spruce is located to the east of the road while the monitor at 500 South Broad is on the west side of the road. If the road is a major source of the sampled particulates, then westerly winds should give a relatively lower ratio of readings (500 S. Broad to South Broad and Spruce) than an easterly wind. Given this relationship, the preponderance of westerly winds would tend to further increase the difference in the two sites. Figures 17 and 18 provide a plot of the measured TSP versus wind direction for the 500 South Broad and the South Broad and Spruce stations during the concurrent sampling period of September through December, 1974. A review of these figures indicates almost identical patterns except for the reduced levels at the 500 South Broad monitor.

Another pair of monitors was operated at the Franklin Institute slightly northwest of the center of the city between November 1974 and June 1975. During this time period 40 samples were taken concurrently. In addition the monitor run by the AMS at the CAMP station at a height of 13 feet off the ground in an area of an unpaved parking lot, a monitor was positioned on the roof of the Institute, approximately 60 feet off the ground and further from the parking lot. Traffic is heavy in this area with an average weekday traffic level of around 105,000 vehicles for the closest four streets in the area (20th, Race, Vine, Benjamin Franklin Parkway) though for the streets close to the CAMP station (20th and Race) the traffic level is much lighter (about 5,000) per day.

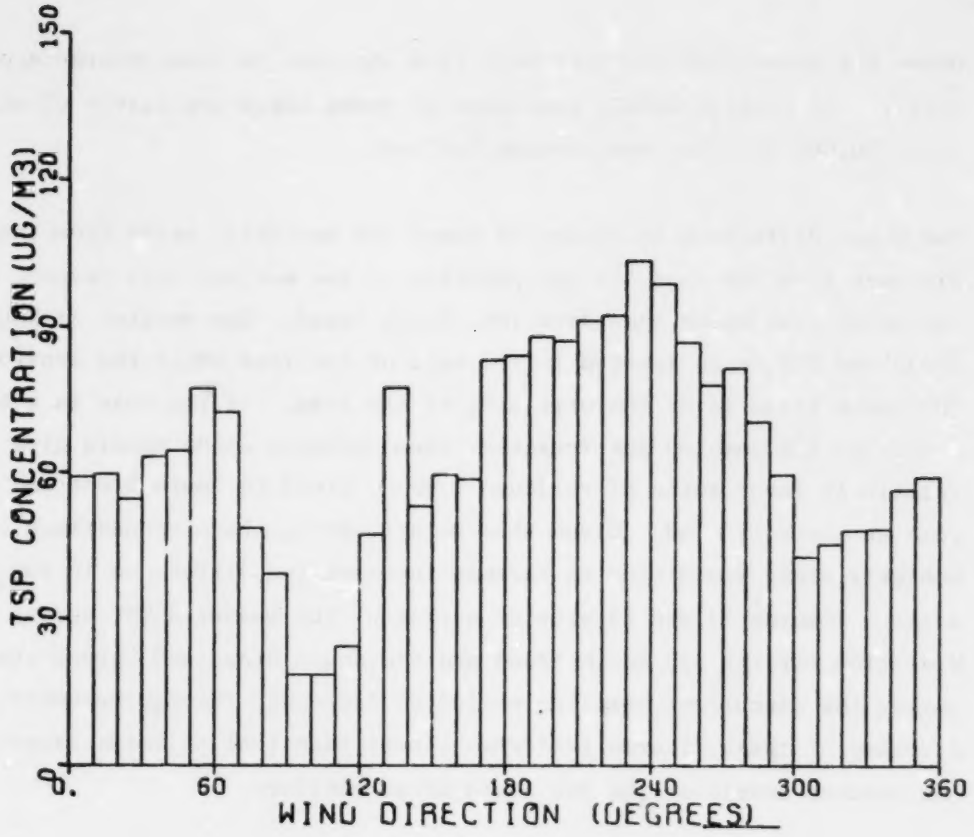


Figure 17. TSP versus wind direction at 500 South Broad Street in Philadelphia, September through December, 1974

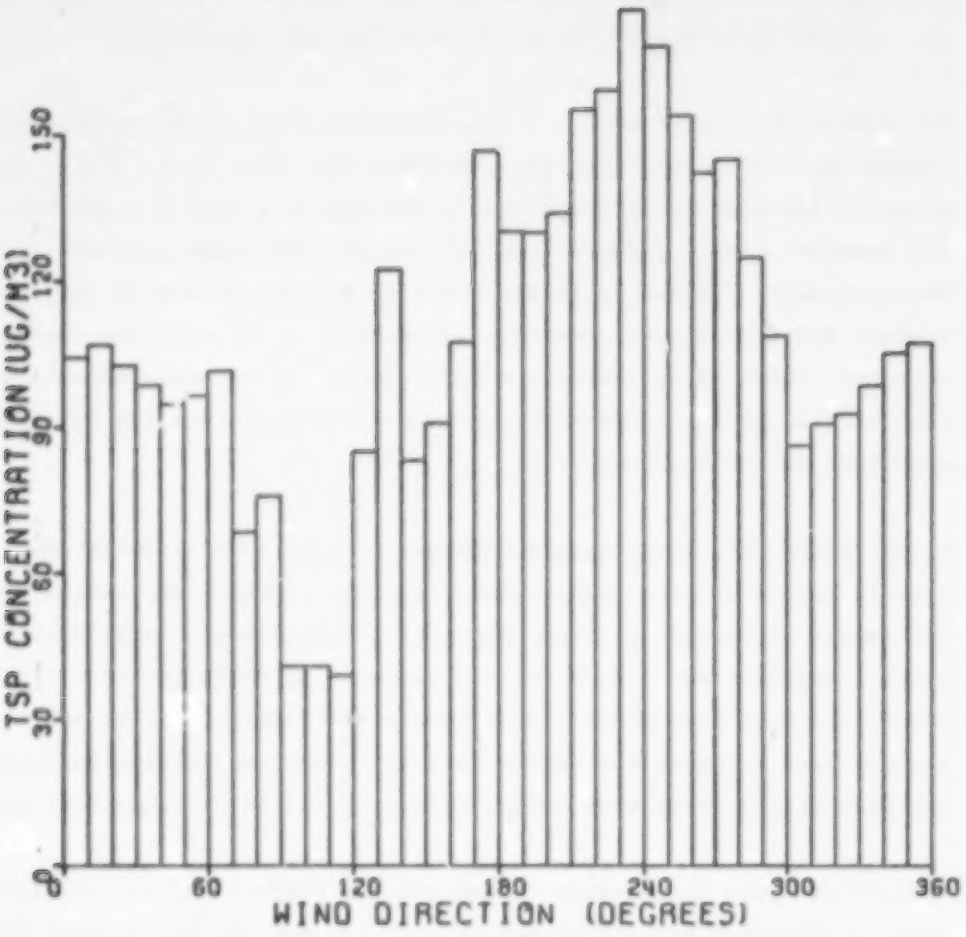


Figure 18. TSP versus wind direction at South Broad and Spruce in Philadelphia, September through December, 1974

The paired observations during this time contained only three pairs of observations during which the rooftop concentrations were higher than those taken at the CAMP station; generally, the ground level concentrations were much higher. The geometric mean for the 40 samples at the rooftop monitor and the CAMP station monitor were 83 and 110, respectively. Using a background of 35 $\mu g/m^3$, the ground level monitor is sampling 56 percent more pollution from urban activity than the rooftop monitor.

To provide an understanding of the direction from which the pollution is coming and to possibly identify contributions from the different roadways, plots of the measured TSP and wind direction were made for the November and December sampling dates (the only months for which meteorological data was available). These plots are given in Figures 19 and 20 for the rooftop and ground level monitors respectively. As with the South Broad monitors, these plots indicate no difference in the measured values at each wind direction between the two monitors other than the relative magnitude of the concentrations.

Variation of TSP Concentration with Day of Week - Daily variations in traffic levels at other monitoring sites can provide some indication of the impact of traffic related emissions on ambient air quality through comparisons with the concentrations measured on different days. Daily TSP levels have been monitored at several Philadelphia sites for a number of years allowing for enough data for a statistically significant analysis of the variations during the weekly cycle of human activity.

Table 9 presents the average concentrations observed at the AMS Laboratory (E. Lycoming Street) by day of week for each of the 3 years 1972, 1973, and 1974, and the average concentrations during these 3 years. Table 9 also shows the average concentration measured at 500 South Broad Street during 1972 - the last year when concentrations were measured daily at this location - by day of the week. Neither hi-vol is located at street level, the hi-vol at South Broad Street being on top of a three-story building (height above ground, 35 feet) and the hi-vol

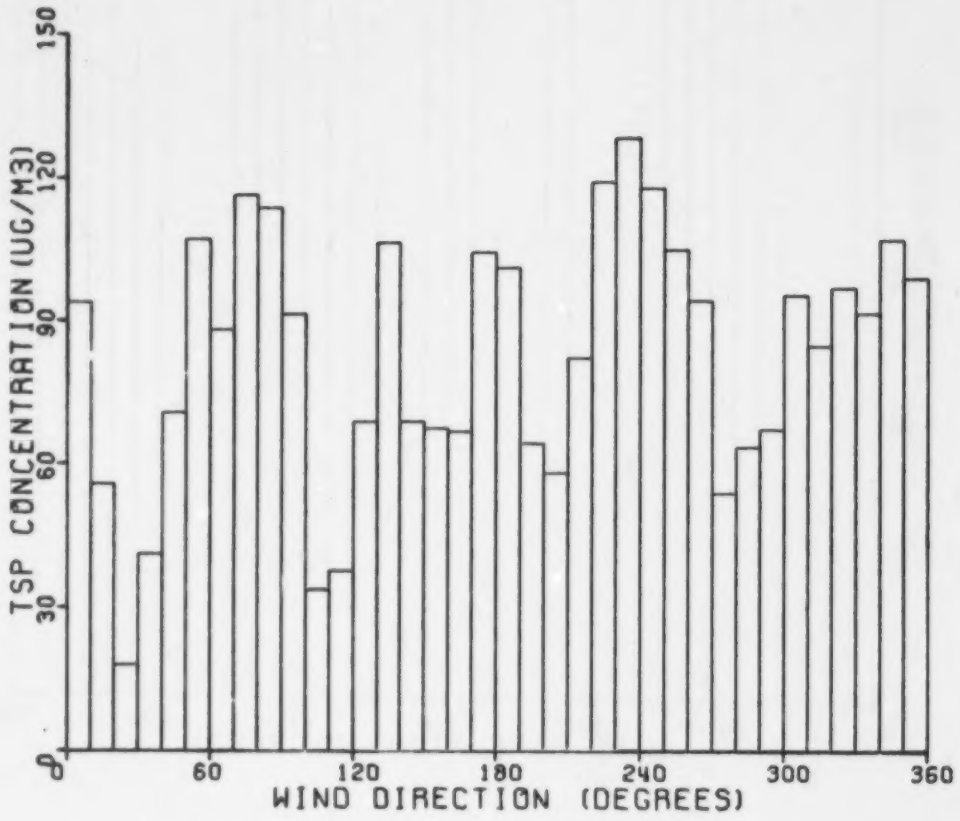


Figure 19. TSP versus wind direction at the Franklin Institute roof-top monitor in Philadelphia, November and December 1974

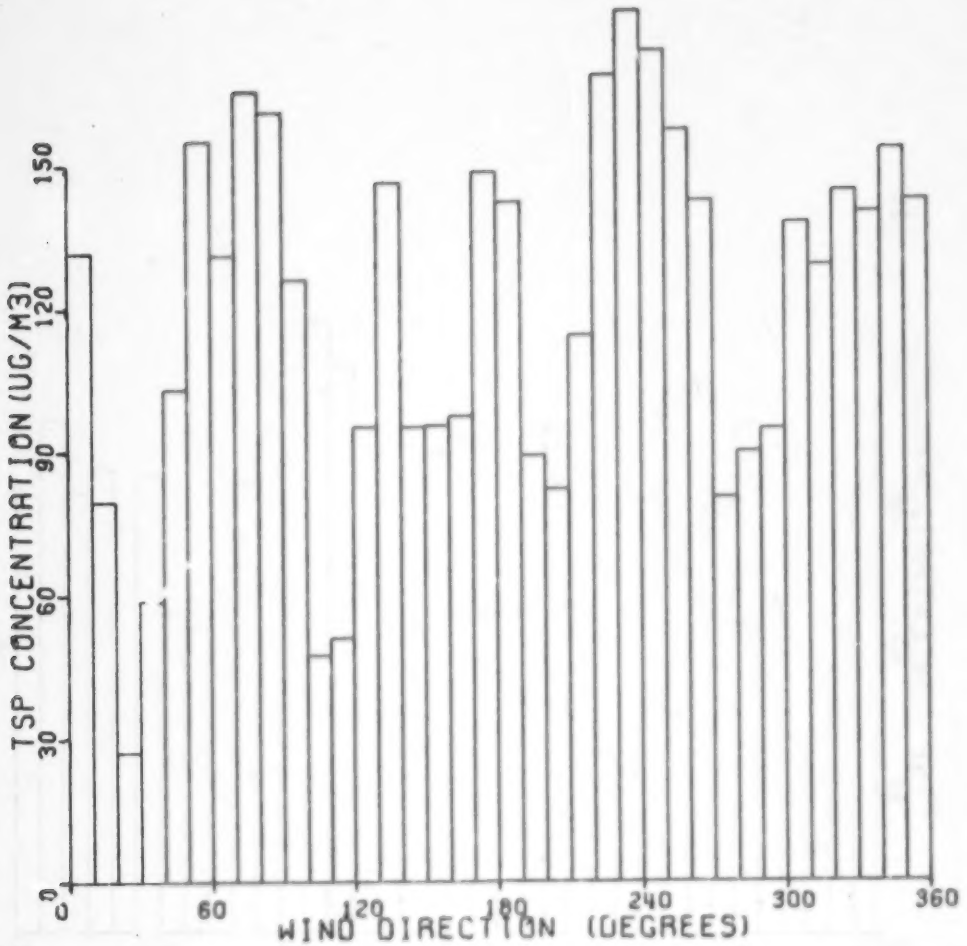


Figure 20. TSP versus wind direction at CAMP in Philadelphia, November and December 1974

Table 9. DAILY VARIATION IN TSP LEVELS AND IN TRAFFIC VOLUMES IN PHILADELPHIA

Site	Year	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Average weekday TSP
		TSP[a]	Ratio[b]	TSP[a]	Ratio[b]	TSP[a]	Ratio[b]	TSP[a]	Ratio[b]	TSP[a]	Ratio[b]	TSP[a]	Ratio[b]	TSP[a]	Ratio[b]	
AMS Lab 1501 E. Lycoming St.	1972	61	0.60	80	1.05	86	1.19	82	1.09	74	0.91	69	0.79	64	0.67	43
	1973	69	0.54	94	0.94	96	0.97	98	1.00	98	1.00	106	1.13	82	0.74	63
	1974	69	0.60	91	0.98	91	0.98	101	1.16	88	0.93	91	0.98	69	0.60	57
	Avg.	64	0.57	84	0.96	90	1.07	91	1.09	83	0.94	83	0.94	70	0.69	51
500 S. Broad St.	1972	61	0.49	82	0.88	94	1.11	89	1.02	87	1.00	91	1.06	76	0.77	53
City-wide traffic[c]	1973		0.60		0.93		0.98		1.00				1.07		0.90	1.00

[a] Average TSP concentration ($\mu g/m^3$).

[b] Ratio = $\frac{\text{Daily TSP-35}}{\text{average weekday TSP-35}}$.

[c] Traffic volume for a specific day of the week divided by average weekday traffic.

at 1501 E. Lycoming Street being on top of the AMS Laboratory roof (height above ground, 17 ft.). The site at 500 South Broad Street is in the downtown commercial area while the AMS Laboratory is located in a mixed residential and light commercial area. Included in this table are the daily variations in city-wide traffic volumes and the ratio of the daily TSP levels to the average weekday levels (the same ratio as the traffic volume data). These ratios are plotted in Figure 21 for a graphical comparison of the data.

It is evident from this data that the fluctuations in daily TSP are closely correlated with the daily changes in the city-wide traffic volumes.

Statistically significant differences exist between the weekend levels and the weekday levels. The fact that the ratios of TSP levels are lower on the weekend than the ratios of traffic volumes could easily be the result of the decrease in activity of other emission sources. In addition, the ratio at 500 South Broad is lower than at the AMS Lab on Sunday but higher on Saturday which is the expected result when comparing a commercial (active Saturday) area to a residential area (relatively more active than a commercial area on Sunday). Unfortunately, data on daily traffic volumes was not available on more than a city-wide basis for comparison.

While the above analysis tends to indicate a close correlation between TSP levels and traffic volumes, daily fluctuations in other emission sources could also be causing much of the noticed correlation. Further analysis was done utilizing the traffic data to determine some way of estimating the contribution of vehicle related emissions to measured TSP concentration.

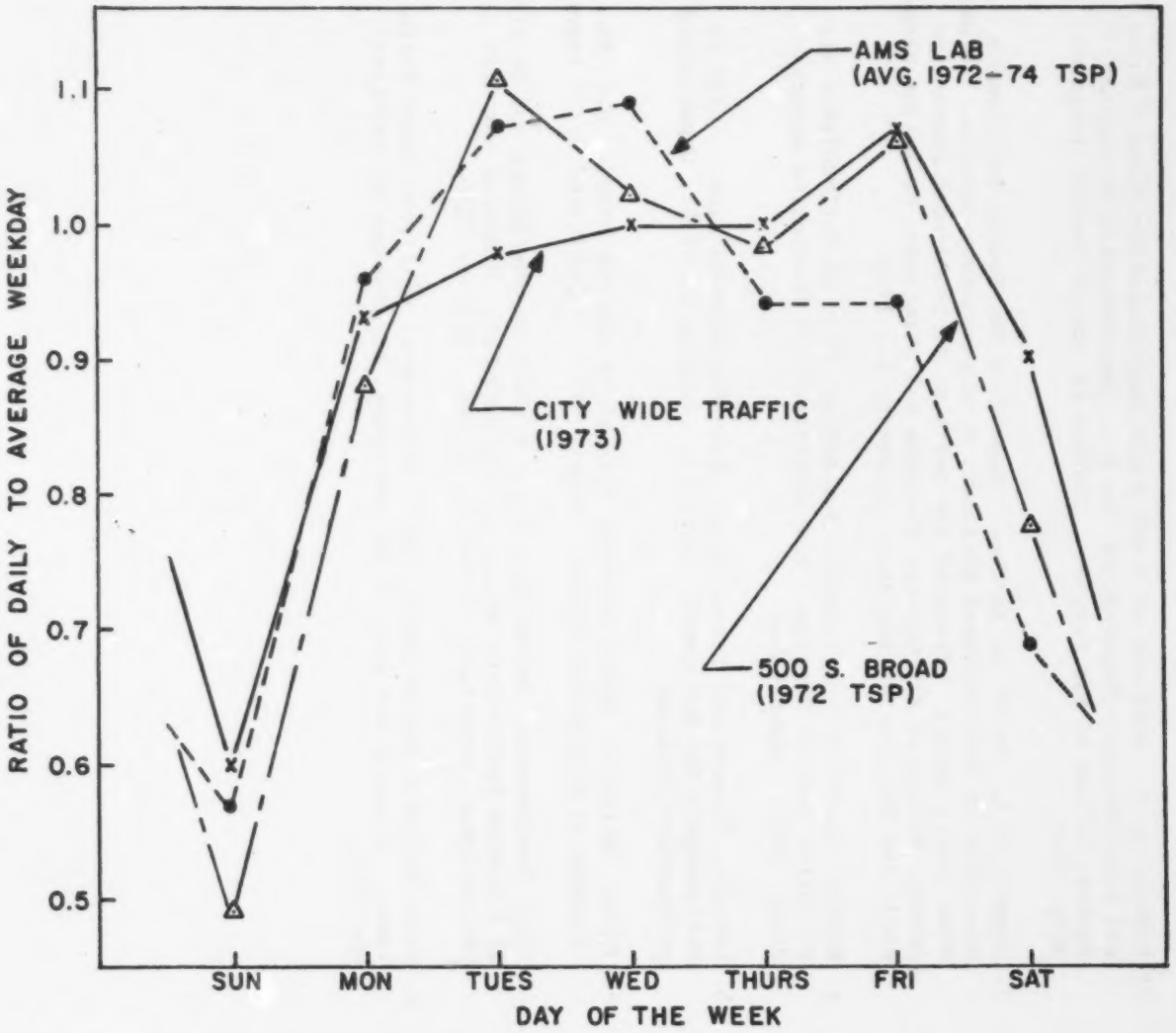


Figure 21. Daily variations in traffic and TSP levels

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SECTION III

SUMMARY AND CONCLUSIONS

The analyses presented in Section II of this report indicated that many factors have contributed to the current situation of ambient TSP concentrations measured in Philadelphia. Such factors have been both totally distinct from each other (e.g., precipitation, monitor siting, annual emission levels, etc.) and interrelated (e.g., space heating emissions and heating degree days). This section attempts to bring together all of these findings for an overall assessment of the particulate problem in Philadelphia.

CITY-WIDE

An appreciable improvement in the ambient air quality with respect to particulates has occurred city-wide in the past 6 years primarily as a result of the reductions in emissions. The emissions are controlled under the more stringent of the applicable regulations of the Commonwealth of Pennsylvania and the City of Philadelphia, the latter of which have been evaluated and found to be relatively stringent compared to other areas studied. The enforcement program operated by the Air Management Services appears to have been reasonably successful and consistently applied.

The improvement in air quality is in reasonable agreement with the improvement projected under the implementation plan for the Commonwealth utilizing rollback calculations. In fact, the city-wide reduction in ambient TSP concentrations between 1969 and 1974 noted in the analysis was greater than would have been expected based on the usual rollback of total emissions. However, some sources are still not in compliance with

the regulations so that further improvement in the air quality may be expected under the currently imposed controls.

The lack of attainment of the primary standard in many parts of the city may be also partially attributed to other reasons. First, since the implementation plan, additional samplers have been added to the network in areas that had higher levels than those previously monitored for the preparation of the SIP. Also many of these are closer to streets and such siting differences have been shown to cause higher readings. These are reviewed further in the discussion of neighborhoods.

Meteorological factors impacting on the air quality are not thought to have been major influences on the problem of attainment or nonattainment of the standards. While precipitation was about 10 percent less than normal in 1974, thereby helping to raise the TSP concentrations, the number of heating degree days was also lower in 1974 and this helped to reduce the emissions from space heating. However, these parameters were shown to have an impact on the city-wide levels and should be considered in reviewing progress and developing further control plans.

Urban activity, specifically construction and traffic, was shown to be an important consideration in the placement of monitoring sites and interpretation of data. While construction has little if any impact on the city-wide levels of TSP, the daily fluctuations in traffic are correlated with the TSP levels and traffic-related emissions may be a major contributing factor in the problem of attainment of the standards. Though the impact of the traffic in an area is only local, the daily variations in traffic volume occur city-wide. Further analysis is needed to determine quantitatively the impact of vehicles on the measured TSP concentrations.

RESIDENTIAL NEIGHBORHOODS

The ambient TSP concentrations measured in the residential neighborhoods of Philadelphia were at or below the primary standard in 1974. The highest level (78 $\mu g/m^3$) was recorded at the most densely populated residential area and the lowest concentration (59 $\mu g/m^3$) was measured at the most rural site. The latter site was poorly placed with respect to the prevailing southwesterly winds which also carry the highest levels of pollution in the area. This, coupled with its having probably the greatest distance back from any roadway, would imply that the air quality levels in that neighborhood are actually exceeding the standards.

Insufficient information was available to indicate the relative impact of the factors that were causing the violations of the standards in these residential neighborhoods. The factors are: the general levels of urban activity in the area, the high concentrations of incoming air (40 to 50 $\mu g/m^3$), and the high degree of industrial activity. The monitoring sites at the AMS Laboratory and the Belmont Filter Station are probably also influenced by the level of traffic in the area.

CENTER CITY

Of the four monitors currently located in the center city area, only two of them - 500 S. Broad and CAMP - were in operation enough of 1974 to provide annual geometric means. Both of these stations exceeded the annual primary standard with means of 76 and 119 $\mu g/m^3$, respectively.

The data collected at a newly located station at S. Broad and Spruce provided a chance for analysis of the impact of distance from the street through comparisons with paired data at the 500 S. Broad monitor. The trends in the data to date indicate that the S. Broad and Spruce monitor will be measuring consistently higher levels of TSP and will further increase the city-wide levels. A similar study was done for the AMS

sampler at the CAMP station on the grounds of the Franklin Institute and consistently lower levels were recorded on the roof of the Institute. The AMS has solved much of the problem of the high levels at the CAMP station by the discontinuance of this site as of June 30, 1975, and using the data of the rooftop sampler.

However, this cannot be considered an appropriate solution to the high levels of TSP in the center city area unless the standards are only applicable to rooftop samplers. The strong correlation found between increasing height of sampler and reductions in TSP levels, as well as the fluctuations in traffic and TSP, provides some evidence that traffic-related emissions need more attention to solve the center city problem. At the same time, it is expected that the trends in inventoried emissions and the corresponding trends in TSP concentration at the 500 S. Broad site indicate that further reductions would be needed in these emissions if the standards are to be met.

INDUSTRIAL NEIGHBORHOODS

All of the monitoring sites in the industrial areas of Philadelphia are exceeding the standards with the lowest value (78 $\mu g/m^3$) recorded at a station with extremely poor ventilation. The relocation of this monitor is likely to produce higher readings for this area. Although there are five sites in industrial areas, it was felt that these monitors did not represent the maximum density of industrial activity and that similarly high or even higher concentrations may be found if they were relocated.

This provides even further difficulty in the attainment of the standards in these areas. Sources are relatively stringently controlled and the monitors are not located so as to be unduly influenced by traffic levels. Therefore, the only approach to the attainment of the standards would have to be through the imposition of more stringent regulations specifically directed at such source categories as fugitive emissions and fugitive dust. Another approach is the reduction of the apparent citywide

influence from urban activity. Both these options may prove untenable from a social and economic viewpoint. Further analysis is most assuredly required and is being performed currently under a separate study.

APPENDIX A

METEOROLOGICAL DATA

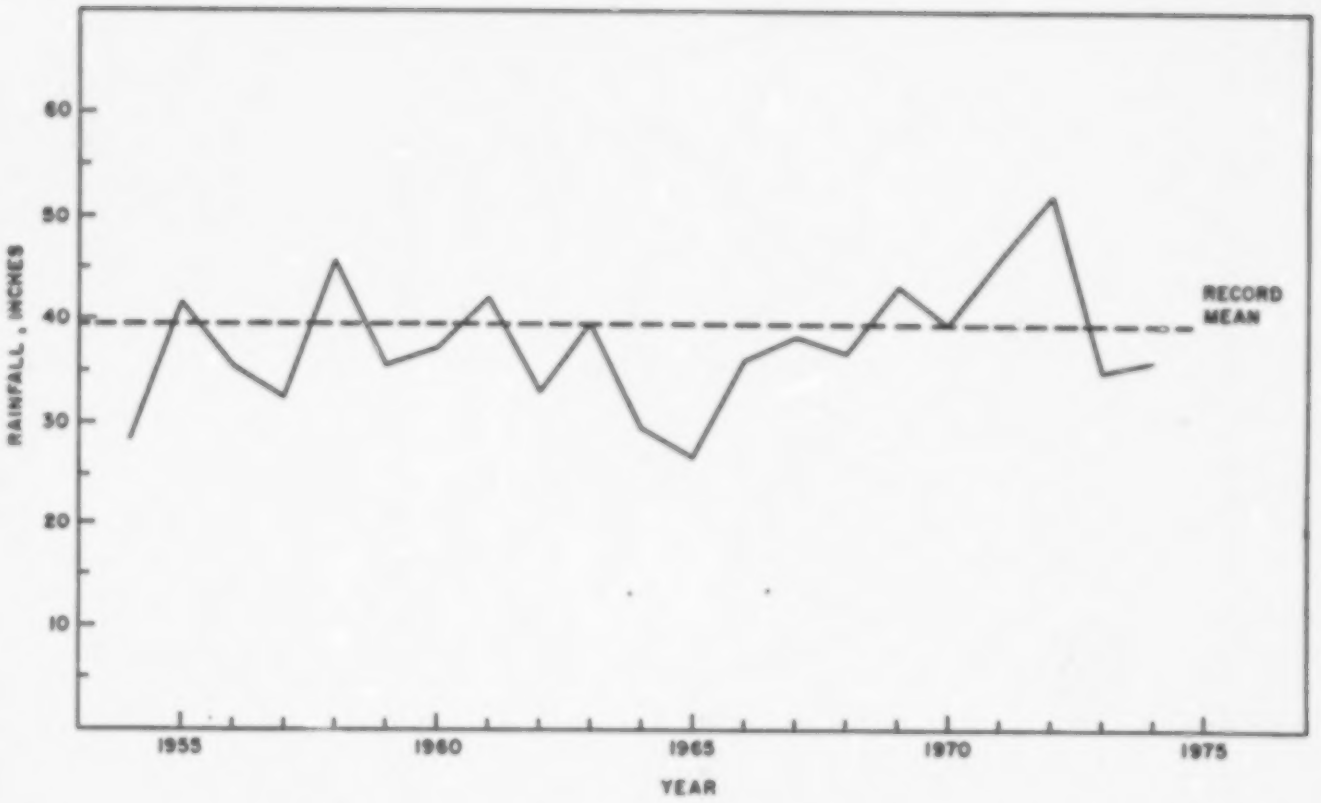

Figure A-1. Yearly rainfall in Philadelphia

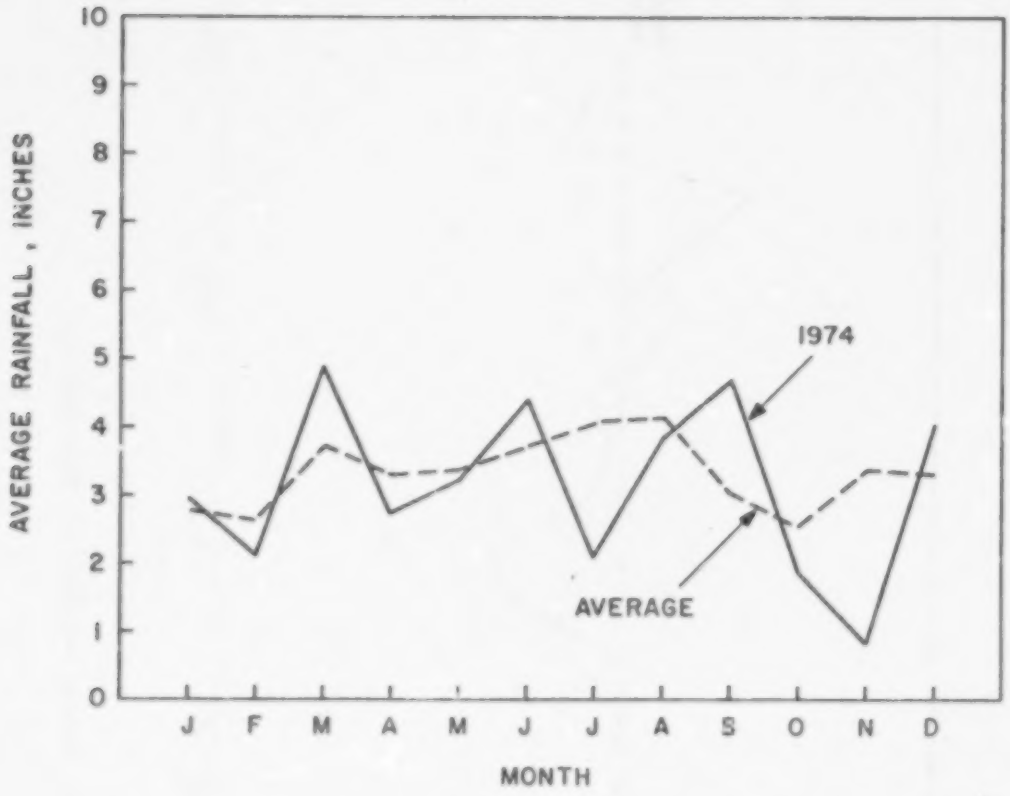

Figure A-2. Monthly rainfall in Philadelphia

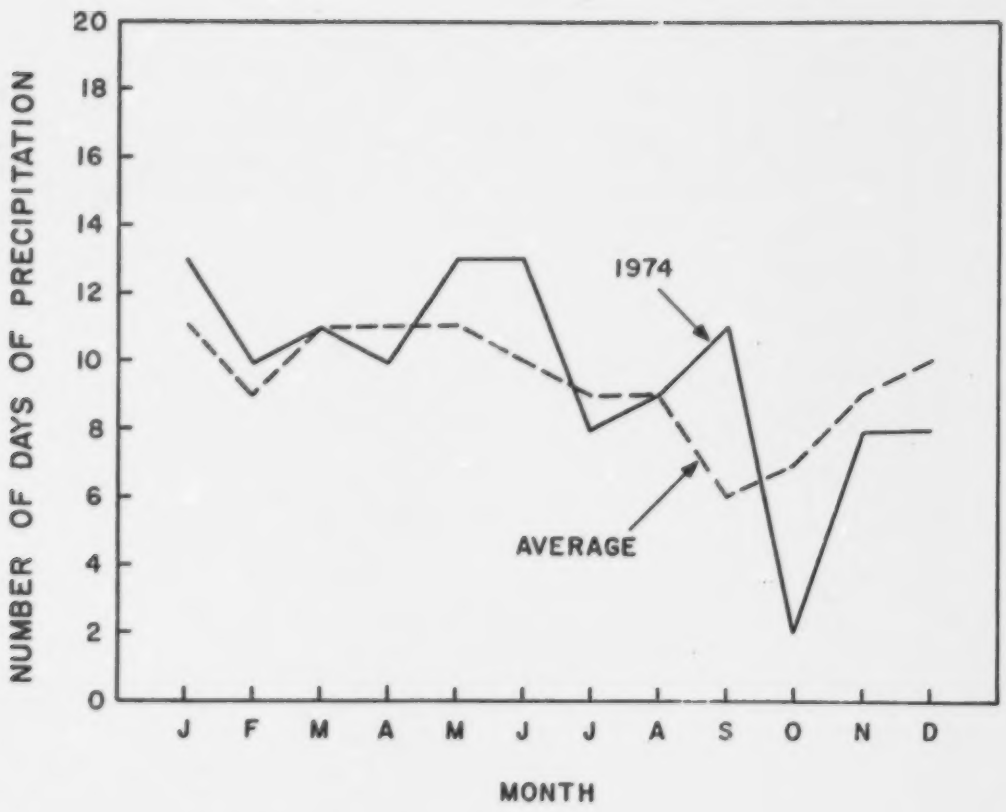

Figure A-3. Monthly number of days of rain in Philadelphia

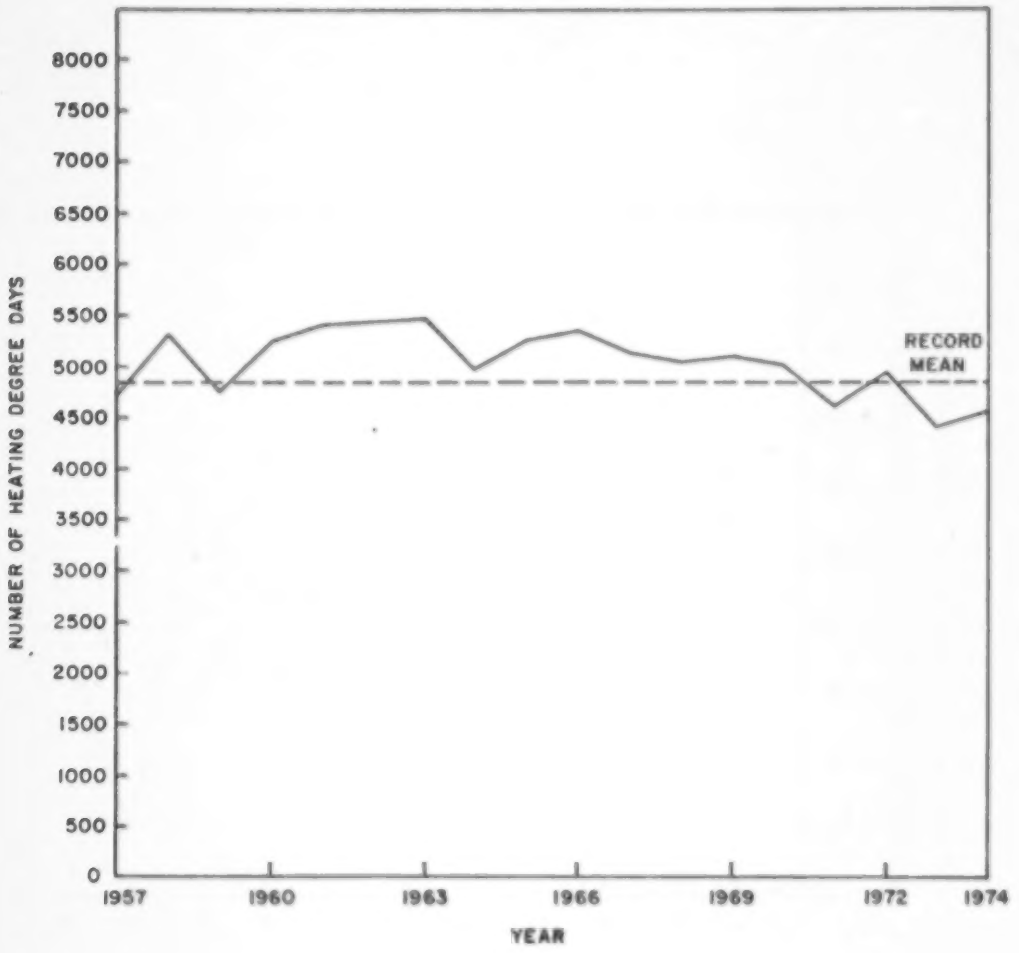

Figure A-4. Yearly heating degree days in Philadelphia

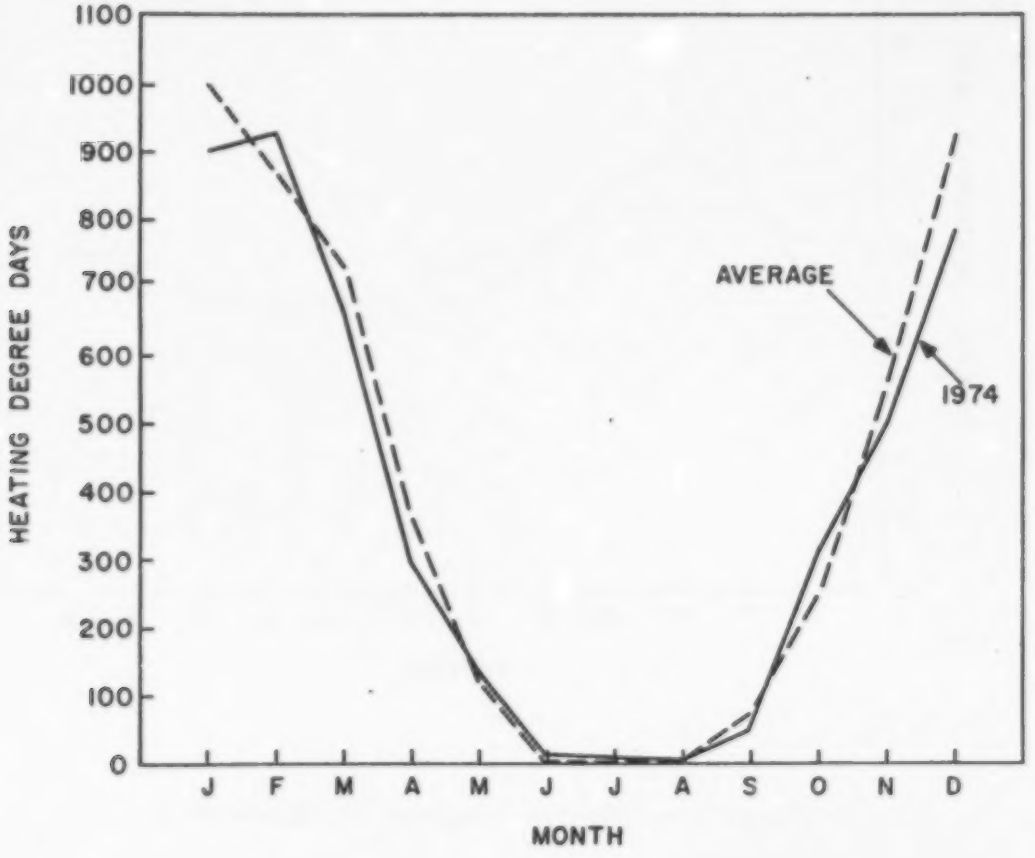

Figure A-5. Monthly heating degree days in Philadelphia

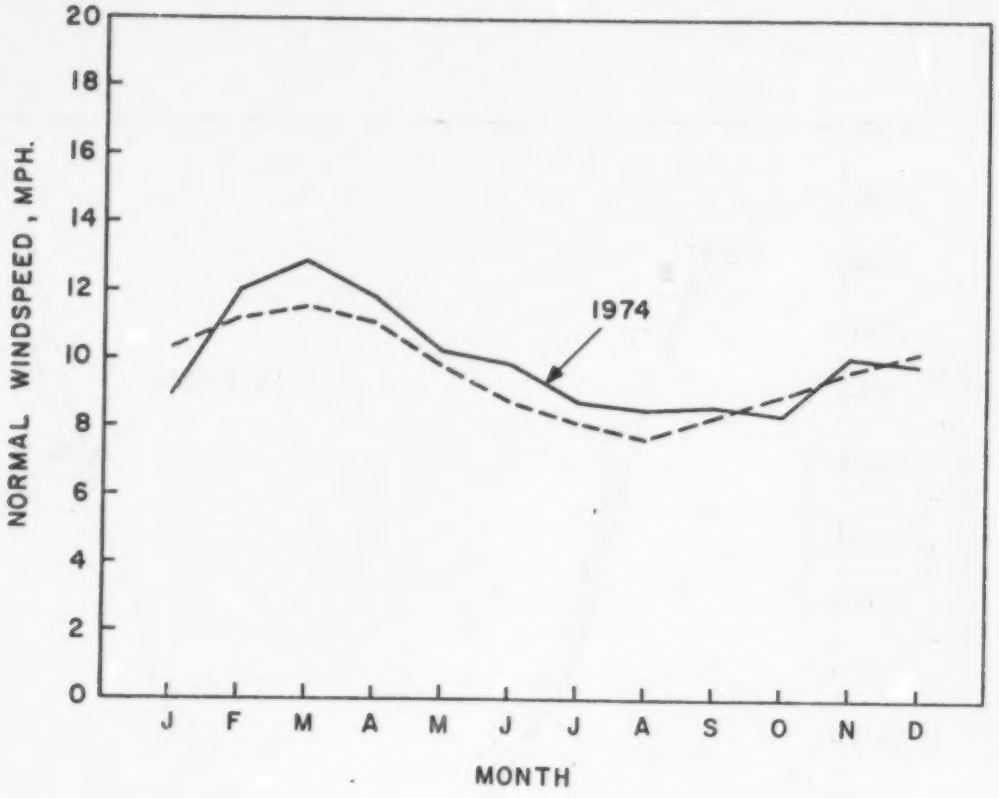

Figure A-6. Monthly windspeed in Philadelphia

APPENDIX B

PARTICLE CHARACTERIZATION

For most of the study cities members of the GCA study team acquired hi-vol filters from the 1974 filter banks of the cognizant local agencies. In addition, several filter samples for 1974 and selected earlier years were obtained from state and federal filter banks. Although some filters underwent chemical and/or detailed physical analysis, the principal purpose of obtaining filters was to utilize optical microscopy to identify each of the constituents that comprised more than 5 percent of the particulate mass. The selected filters, which were representative of several different site types and TSP levels within each study area, were returned to a clean room at GCA/Technology Division and carefully inspected for artifacts and evidence of sampler or filter malfunctions.

Each filter was then assigned a randomly generated five-digit number which served as the only identifier for the filter sample so that each analyst had no information concerning the city, site, TSP loading or probable local sources associated with the sample. Furthermore, the use of two laboratories for the microscopy, coupled with the randomly generated identifying numbers, permitted a fairly comprehensive quality control program in the form of blind replicate analyses. Since both laboratories utilized more than one analyst, these procedures resulted in as many as four microscopists observing samples from the same filter and, in some cases, the same analyst examining replicate samples from the same filter as many as three times.

The results of this quality control effort, which are presented in Volumes I and II, warn against relying very heavily on the results of any one filter analysis. However, the random match-up between analyst and filter sample should minimize systematic bias in composited results.

Forty filters from eleven sites were selected for analysis in Philadelphia and Table B-1 summarizes the meteorological data for the selected sampling days. To gain some insight into the contribution of secondary particulate, much of which is too small to be observed by the microscopists, the annual average sulfate and nitrate concentrations for the NASN site are shown in Table B-2. The results for each of the filters submitted for routine analysis from all sites except the NASN site are presented in Table B-3. The results for the filters at each site have been averaged to give a composite of the particulate composition as shown in Table B-4. Seven filters underwent replicate analyses, and the results of this task are presented in Table B-5.

Philadelphia was one of three study cities selected for particulate trends analysis. To accomplish this task, two or three filters for each of the calendar years 1965, 1970, 1971, 1973, and 1974 from NASN sampling sites were selected for microscopic analysis. The results of each filter analysis are presented in Table B-6 and a composite summary for each year is presented in Table B-7. Operation of the NASN site of historical interest was terminated at the end of 1973, so filters from two other NASN sites in Philadelphia were selected for 1974. In order to eliminate the complicating factor of site location, only the interval of 1965 and 1973 will be considered for the purpose of trend analysis.

It can be seen from Table B-7 that there has been a consistent increase in the percent contribution of minerals since 1965. During the same time the contribution of combustion products has been decreasing. The overall particulate loadings at that site have also shown marked decreases with the annual geometric mean going from 170 $\mu g/m^3$ in 1965

to 89 $\mu g/m^3$ in 1973. This indicates that even though the percent contribution of minerals is on the increase, the net concentration may be decreasing.

Of the eight non-NASN sites from which filters were analyzed for 1974, only one (Allegheny) showed higher amounts of combustion products than minerals. This site is in an industrial area and had the highest 1974 annual geometric mean of all sites in Philadelphia. All the other sites shown in Table B-4 displayed a predominance of mineral material with the average values at each site ranging from 55 percent to 87 percent. Two sites were located so as to allow a comparison of sampler height with TSP levels and composition. The Camp station, 8A, is located in a parking lot adjacent to the Franklin Research Institute and the sampler is 13 feet off the ground. Another sampler is located in the roof of the Institute approximately 60 feet off the ground. The geometric mean for the 40 paired samples at the rooftop monitor and the Camp station monitor were 83 $\mu g/m^3$ and 110 $\mu g/m^3$, respectively. Filters from the two sites were examined microscopically for two sampling days and the results are shown in Table B-3e. On November 1, 1974, the lower sampler had a much higher concentration presumably caused by local fugitive dust, probably generated by the parking lot. The higher percentage of minerals at the Camp station confirms that observation. On December 19, 1974, the composition at the two sites was very similar, however, and there is no evidence of monitor height influencing the results.

The composite particulate composition for all 1974 non-NASN filters from Philadelphia that underwent analyses, presented in Table B-8, shows that the minerals quartz, calcite, and hematite account for nearly twice as much of the particulate mass as do combustion products. The average percent minerals is quite typical of the other 14 study cities (eighth highest) but the average percent combustion products is high (fourth highest). Philadelphia was ranked among the lowest study cities in regard to average percent biological and rubber content.

Three of the filters from Philadelphia were also submitted for determination of particle size as a function of particle type, as shown in Figures B-1 through B-3. Two of these samples were subjected to chemical analyses. The sample from Broad and Lombard on December 19, 1974, had 9 $\mu g/m^3$ benzene solubles and about 18 $\mu g/m^3$ total carbon with most reported as organic carbon. The sample from Broad and Spruce on November 19, 1974, had 11 $\mu g/m^3$ benzene solubles and about 32 $\mu g/m^3$ total carbon, again nearly all reported as organic carbon.

This latter sample was also selected for detailed physical analysis, and the results are presented in Table B-9. The Philadelphia Air Management Services Laboratory runs chemical analyses on daily samples collected at selected sites in the city. The results of some of these analyses are presented in Tables B-10 through B-17.

Table B-1. METEOROLOGICAL DATA ON SELECTED SAMPLING DAYS (INTERNATIONAL AIRPORT, PHILADELPHIA)

Date	Precipitation (in.)		Wind speed (mph)		Wind direction (deg)	
	Day of obs.	Preceding day	Average	Resultant	3-hour observation	Resultant
6/09/65						
10/07/65						
12/22/65						
3/24/70	t	t	12.1	11.4	240, 220, 230, 260 240, 280, 260, 250	250
8/26/70	0	0	6.9	6.3	200, 210, 220, 200 190, 230, 270, 200	210
9/22/70	0	0	8.2	7.9	200, 210, 220, 240 220, 220, 180, 210	210
1/19/71	0	0	9.5	9.1	260, 310, 260, 300 300, 280, 290, 270	280
12/03/71	0	0	6.5	5.4	330, 310, C, 290 220, 290, 290, 290	280
12/11/71	0	t	11.8	7.7	180, 210, 230, 280 320, 330, 290, 240	270
1/23/72	t	0.01	6.6	3.6	110, 100, 320, 220 290, 240, 230, 170	220
1/23/74	0	0	7.1	3.4	100, 90, C, 290 260, 240, 240, 340	270
9/08/74	0	0.79	5.5	2.9	350, 80, 350, 100 140, 130, 190, 140	120
9/26/74	0	0	7.1	5.8	260, 260, 280, 230 290, 320, 210, 240	270

Table B-1 (continued). METEOROLOGICAL DATA ON SELECTED SAMPLING DAYS (INTERNATIONAL AIRPORT, PHILADELPHIA)

Date	Precipitation, in.		Wind speed, mph		Wind direction, deg	
	Day of obs.	Preceding day	Average	Resultant	3-hour observation	Resultant
11/01/74	0	0	6.8	6.4	230, 230, 240, 250 230, 280, 230, 250	250
11/19/74	0	0	6.8	5.8	230, 260, 270, 250 240, 230, 180, 170	230
12/07/74	0.07	0	8.1	3.4	360, 10, 70, 70 200, 190, 130, 150	120
12/19/74	t	0	6.9	5.6	240, 250, 170, 140 230, 230, 180, 220	210

Note: C = Calm
t = Trace

Table B-2. ANNUAL AVERAGE CONCENTRATION OF SULFATE AND NITRATE IONS AT THE PHILADELPHIA, PENNSYLVANIA NASN SITE NO. 397140001 FOR 1972 AND 1973 AND SITE NO. 397140004 FOR 1974 ($\mu g/m^3$)

Year	Sulfate		Nitrate	
	Arithmetic mean	Geometric mean	Arithmetic mean	Geometric mean
1972	16.14	14.16	3.36	3.08
1973	13.51	12.13	4.85	3.81
1974	15.24	13.33	4.14	3.66

Table B-3a. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN PHILADELPHIA AND VICINITY (BROAD AT SPRUCE — NO. 10)

Date	8 September 1974			26 September 1974			19 November 1974			7 December 1974			19 December 1974		
TSP ($\mu g/m^3$)	123			161			189			112			169		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(9)			(7)			(9)			(5)	<1-150	15	(5)	1-50	9
Quartz	6	<1-100	5	4	<1-160	5	4+	<1-160	5	2+			3		
Calcite	1+	<1-100	5	1+	<1-100	5	3	<1-50	5	1			1		
Feldspars	1-			1-											
Hematite	1+	<1-60	0.5	1	<1-20	0.5	1	<1-50	0.5	2-			1		
Mica															
Combustion Products	(1)			(1-)			(1)			(5-)	<1-180	1	(2)	<1-80	2
Soot:															
Oil	1-	<1-175	0.5	1-			1								
Coal															
Soot															
Glassy fly ash													1		
Incinerator fly ash													1		
Burned wood															
Burned paper															
Magnetite															
Biological Material	(0+)			(0+)			(0+)			(0+)			(0+)		
Pollen															
Spores															
Paper															
Starch															
Misc. plant tissue															
Miscellaneous	(0+)			(2+)			(0+)			(0+)			(3)	8-60	20
Iron or steel															
Rubber				2+	<1-800	100							3		

Table B-3b. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN PHILADELPHIA AND VICINITY (BROAD AT LOMBARD — NO. 12)

Date	23 January 1974			8 September 1974			26 September 1974			19 November 1974			7 December 1974			19 December 1974		
TSP ($\mu g/m^3$)	141			56			100			115			91			94		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(5+)			(9)			(8+)			(9)			(4)	1-60	2	(1-)	<1-75	8
Quartz	2	1-50	15	5	<1-75	5	4	<1-50	5	4	<1-80	5	1					
Calcite	1	1-75	10	1+	<1-75	5	2+	<1-50	5	3	<1-50	5						
Feldspars	1-	1-30	10				1-			1-								
Hematite	2	1-10	1	2+	<1-20	0.5	1+	<1-20	0.5	1+	<1-30	0.5	2+					
Mica																		
Combustion Products	(4+)			(1)			(2-)			(1)			(6)	<1-45	2	(8+)	<1-80	<1
Soot:																		
Oil	4	<1-120	<0.5	1-	<1-200	0.5	1	<1-120	0.5	1-			6					
Coal	1-																	
Soot																		
Glassy fly ash							1-									8+		
Incinerator fly ash																		
Burned wood																		
Burned paper																		
Magnetite																		
Biological Material	(0+)			(0+)			(0+)			(0+)			(0+)			(1)	6-15	12
Pollen																		
Spores																		
Paper																		
Starch																		
Misc. plant tissue																1		
Miscellaneous	(0+)			(0+)			(0+)			(0+)			(0+)					
Iron or steel																		
Rubber																		

Table B-3c. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN PHILADELPHIA AND VICINITY (DEFENSE — NO. 1, ALLEGHENY — NO. 2, AND BELMONT — NO. 4)

Site	Defense — No. 1			Allegheny — No. 2									Belmont — No. 4					
Date	26 September 1974			19 November 1974			7 December 1974			19 December 1974			23 January 1974			19 November 1974		
TSP ($\mu g/m^3$)	163			175			100			109			111			115		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(9-)			(8)			(4)	<1-45	2	(1)	<1-2	1	(5+)	1-45	11	(7)		
Quartz	3+	<1-100	5	1+	<1-50	5	2-			1-			3+			1	<1-40	5
Calcite	3+	<1-100	3	2+	<1-75	5	1						2-			1+	<1-40	5
Feldspars				1-												1-		
Hematite	1+	<1-50	0.5	4	<1-30	<0.5	1+									4	<1-50	0.5
Mica																		
Combustion Products	(1+)			(1)			(6)	<1-70	<1	(9)	<1-90	<1	(4+)			(3)		
Soot:																		
Oil	1	<1-400	0.5	1-	<1-50	0.5												
Coal																2	<1-100	0.5
Soot							6			9			1+					
Glassy fly ash													3			1	1-25	6
Incinerator fly ash																		
Burned wood																		
Burned paper																		
Magnetite																		
Biological Material	(0+)			(1)			(0+)			(0+)			(0+)			(0+)		
Pollen																		
Spores																		
Paper																		
Starch				1	3-25	12												
Misc. plant tissue																		
Miscellaneous	(0+)			(0+)			(0+)			(0+)			(0+)			(0+)		
Iron or steel																		
Rubber																		

Table B-3d. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN PHILADELPHIA AND VICINITY (N. E. AIRPORT – NO. 6)

Date	23 January 1974			8 September 1974			26 September 1974			19 November 1974			7 December 1974		
TSP ($\mu g/m^3$)	107			99			206			106			72		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(8+)			(9+)			(9)			(8)			(2+)	<1-75	3
Quartz	3	<1-50	10	6	<1-150	2	6	<1-50	5	4	<1-75	5	1		
Calcite	3	<1-50	5	2	<1-100	5	1+	<1-50	5	3	<1-50	5			
Feldspars	1-														
Hematite	2	<1-20	0.5	1	<1-50	0.5	1	<1-15	0.5	1	<1-30	0.5	1		
Mica															
Combustion Products	(2-)			(1-)			(1)			(2)			(8-)	<1-300	<1
Soot:															
Oil	1	<1-50	0.5	1-			1	<1-50	0.5	1	<1-150	0.5			
Coal															
Soot															
Glassy fly ash	1-									1-	1-15	5	8-		
Incinerator fly ash															
Burned wood															
Burned paper															
Magnetite															
Biological Material	(0+)			(0+)			(0+)			(0+)			(0+)		
Pollen															
Spores															
Paper															
Starch															
Misc. plant tissue															
Miscellaneous	(0+)			(0+)			(0+)			(0+)			(0+)		
Iron or steel															
Rubber															

Table B-3e. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN PHILADELPHIA AND VICINITY (CAMP – NO. 8A, FRI ROOF – NO. 8B)

Site	CAMP – No. 8A						FRI Roof – No. 8B					
Date	1 November 1974			19 December 1974			1 November 1974			19 December 1974		
TSP ($\mu g/m^3$)	264			NA[a]			199			133		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(9+)			(4)	1-45	6	(7)			(4)	<1-66	4
Quartz	1+	<1-100	15	1			3	<1-80	5	3		
Calcite	7	<1-100	15	3-			2+	<1-80	5	1		
Feldspars												
Hematite	1	<1-50	0.5				1	<1-20	0.5	1-		
Mica												
Combustion Products	(1-)			(6)	1-20	1	(3)			(5+)	<1-50	2
Soot:												
Oil							1-	<1-100	0.5			
Coal												
Soot				5						4		
Glassy fly ash	1-			1-			2+	1-15	3	1+		
Incinerator fly ash												
Burned wood												
Burned paper												
Magnetite												
Biological Material	(0+)			(0+)			(0+)			(0+)		
Pollen												
Spores												
Paper												
Starch												
Misc. plant tissue												
Miscellaneous	(0+)			(0+)			(0+)			(1-)	5-58	25
Iron or steel												
Rubber										1-		

[a]Not Available

Table B-4. COMPOSITE SUMMARY OF FILTER ANALYSES FOR SELECTED SITES IN PHILADELPHIA AND VICINITY

Site	Broad & Lombard – No. 12		Broad & Spruce – No. 10		N.E. Airport No. 6		Camp – No. 8A		FRI Roof No. 8B		Belmont No. 4		Allegheny No. 2		Defense – No. 1
No. of filters	6		5		5		2		2		2		3		1
	Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent
Components	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	–
Minerals	(60)	6-90	(69)	49-90	(74)	23-93	(67)	40-93	(55)	42-68	(62)	55-69	(44)	10-82	(87)
Quartz	27	2-48	39	29-58	40	10-60	13	10-15	30	29-30	22	10-34	12	6-16	35
Calcite	14	1-30	16	9-30	19	1-30	47	27-68	16	8-25	15	15-16	12	2-25	35
Feldspars	2	0-5	2	0-4	2	0-4	1	0-2	2	0-3	2	0-4	1	0-4	2
Hematite	17	0-25	12	8-16	12	10-20	6	3-8	7	5-10	23	5-40	19	2-38	15
Mica			<1		1	0-2			<1						<1
Combustion Products	(37)	8-84	(19)	6-47	(26)	7-77	(33)	7-60	(42)	32-53	(38)	31-45	(52)	8-89	(13)
Soot:															
Oil	20	0-60	4	0-10	7	0-10	1	0-2	2	0-5	9	0-18	2	0-6	10
Coal	2	0-4	1	0-2	1	0-2	1	0-1	1	0-2	9	3-15	<1	0-1	1
Soot	14	0-84	11	0-47	16	0-77	26	0-53	19	0-38			49	0-88	
Glassy fly ash	1	0-4	3	0-11	2	0-6	5	4-7	20	15-25	20	10-30	1	0-1	1
Incinerator fly ash	<1		<1		<1				<1		<1				1
Burned wood	<1								<1						
Burned paper	<1		<1		<1				<1		<1				
Magnetite															
Biological Material	(2)	0-10	(<1)		(<1)		(<1)		(<1)		(<1)		(3)	0-10	(<1)
Pollen	<1		<1		<1		<1		<1						<1
Spores	<1		<1		<1		<1		<1		<1		<1		<1
Paper	<1	0-1	<1		<1		<1		<1				<1		<1
Starch	2	0-10	<1		<1		<1		<1				3	<1-10	
Misc. plant tissue	<1		<1		<1		<1		<1		<1		<1		<1
Miscellaneous	(<1)	0-2	(12)	0-30	(<1)		(<1)		(3)	0-5	(<1)		(<1)	0-1	(<1)
Iron or steel	<1		<1		<1		(<1)		(<1)		<1		<1		<1
Rubber	<1	0-2	12	0-30	<1				3	<1-5			<1	0-1	

Table B-5. RESULTS OF REPLICATE ANALYSES OF PHILADELPHIA FILTERS

Site	Broad & Lombard – No. 12						Allegheny – No. 2	
Date	23 January 1974		26 September 1974		19 December 1974		19 December 1974	
TSP ($\mu g/m^3$)	141		100		94		109	
Laboratory	A	A	A	B	A	B	A	B
Analysis	1	2	1	1	1	1	1	1
Components								
Minerals	(55)	(66)	(84)	(11)	(6)	(22)	(10)	(7)
Quartz	20	31	40		2		6	
Calcite	10	25	25		1		2	
Feldspars	5	4	4					
Hematite	20	6	15		3		2	
Mica		<1						
Combustion Products	(44)	(34)	(16)	(89)	(84)	(77)	(89)	(47)
Soot:								
Oil	40	25	10					
Coal	4	2	2	13	84	28	88	
Soot							<1	
Glassy fly ash		2	4					47
Incinerator fly ash		1		76		49		
Burned wood	<1							
Burned paper	<1	4						
Magnetite								
Biological Material	(1)	(<1)	(<1)		(10)	(1)	(<1)	(46)
Pollen		<1	<1					
Spores	<1	<1	<1					
Paper	1	<1	<1				<1	
Starch	<1	<1	<1		10		<1	
Misc. plant tissue	<1	<1	<1					
Miscellaneous	(<1)	(<1)	(<1)					
Iron or steel	<1	<1	<1					
Rubber								

Table B-6a. RESULTS OF FILTER ANALYSES FOR TRENDS AT NASN SITE NO. 397140001 IN PHILADELPHIA (1965 AND 1970)

Date	9 June 1965			7 October 1965			22 December 1965			24 March 1970			26 August 1970			22 September 1970		
TSP ($\mu g/m^3$)	170			215			279			136			166			287		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size μm
Minerals	(6+)			(4+)			(6)			(6+)			(7)			(6+)		
Quartz	3	<1-60	3	2	<1-40	5	3	<1-125	5	3+	<1-240	5	3	<1-50	5	3	<1-80	5
Calcite	2	<1-40	3	1	<1-40	5	1+	<1-125	5	1+	<1-50	5	2	<1-50	5	1+	<1-60	5
Feldspars	1-									1-			1-			1-		
Hematite	1	<1-40	0.5	1	<1-60	0.5	1	<1-80	0.5	1	<1-30	0.5	1+	<1-40	0.5	1+	<1-80	0.
Mica																		
Combustion Products	(3-)			(6-)			(3+)			(3-)			(1+)			(2)		
Soot:																		
Oil	2	<1-140	0.5	4+	<1-120	0.5	3	<1-200	0.5	2	<1-120	0.5	1	<1-150	0.5	1+	<1-120	0.
Coal																		
Glassy fly ash	1-			1						1-			1-	<1-30	10	1-		
Incinerator fly ash																		
Burned wood																		
Burned paper																		
Magnetite																		
Biological Material	(0+)			(0+)			(0+)			(0+)			(0+)			(0+)		
Pollen																		
Spores																		
Paper																		
Starch																		
Misc. plant tissue																		
Miscellaneous	(1)			(0+)			(1-)			(1)			(1+)			(1+)		
Iron or steel																		
Rubber	1	<1-14	30				1-	<1-125	30	1	<1-100	30	1+	<1-150	30	1+	<1-150	30

Table B-6b. RESULTS OF FILTER ANALYSES FOR TRENDS AT NASN SITE NO. 397140001 IN PHILADELPHIA (1971 AND 1973)

Date	19 January 1971			3 December 1971			11 December 1971			22 April 1973			12 November 1973		
TSP ($\mu g/m^3$)	95			136			200			338			120		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(7+)			(7-)			(7)			(7)			(7+)		
Quartz	3	<1-50	8	2+	<1-50	3	3	<1-80	5	3	<1-100	3	3	<1-80	3
Calcite	3	<1-50	8	2	<1-75	3	2+	<1-80	5	3	<1-80	3	3	<1-80	3
Feldspars							1-			1-					
Hematite	1	<1-20	0.5	2	<1-8	0.5	1	<1-80	0.5	1	<1-40	0.5	1	<1-50	0.5
Mica															
Combustion Products	(1+)			(2+)			(3-)			(1)			(2)		
Soot:															
Oil	1	<1-10	0.5	2+	<1-150	0.5	2	<1-150	0.5	(1)	<1-75	0.5	1		
Coal															
Glassy fly ash							1-						1	<1-40	10
Incinerator fly ash															
Burned wood															
Burned paper															
Magnetite															
Biological Material	(0+)			(0+)			(0+)			(1)			(0+)		
Pollen										1	<10-50	16			
Spores															
Paper															
Starch															
Misc. plant tissue															
Miscellaneous	(1)			(1)			(1-)			(1)			(1-)		
Iron or steel															
Rubber	1	<1-80	40	1	<1-100	30	1-	<1-100	40	1	<1-150	30	1-	<1-100	40

Table B-6c. RESULTS OF FILTER ANALYSES FOR TRENDS AT NASN SITE NOS. 391740002 AND 397140004 IN PHILADELPHIA (1974)

Site	397140002			397140004					
Date	23 January 1974			8 September 1974			19 November 1974		
TSP ($\mu g/m^3$)	NA[a]			48			151		
Components	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm	Quantity, tenths	Size range, μm	Avg. size, μm
Minerals	(7+)			(5+)			(3)	<1-45	3
Quartz	3	<1-80	5	2+	<1-80	2	1		
Calcite	3	<1-100	5	1+	<1-50	2	1		
Feldspars									
Hematite	1	<1-20	0.5	1	<1-	0.5	1		
Mica									
Combustion Products	(2-)			(2)			(6+)	<1-30	7
Soot:									
Oil	1	<1-100	0.5	2	<1-50	0.5	2+		
Coal									
Fine soot							4		
Glassy fly ash	1-	<1-15	2						
Incinerator fly ash									
Burned wood									
Burned paper									
Magnetite									
Biological Material	(0+)			(0+)			(0+)		
Pollen									
Spores									
Paper									
Starch									
Misc. plant tissue									
Miscellaneous	(1)			(2+)			1-	5-270	30
Iron or steel									
Rubber	1	<1-125	30	2+	<1-100		1-		

[a] Not Available

Table B-7. COMPOSITE SUMMARY OF FILTER ANALYSES FOR NASN SITES IN PHILADELPHIA AND VICINITY (BY YEARS)

Site No.	397140001		397140001		397140001		397140001		397140002	397140004	
Year	1965		1970		1971		1973		1974	1974	
No. of filters	3		3		3		2		1	2	
	Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent	Quantity percent	
Components	Average	Range	Average	Range	Average	Range	Average	Range	–	Average	Range
Minerals	(56)	43-64	(66)	64-69	(70)	67-75	(72)	70-75	(73)	(41)	28-53
Quartz	27	20-30	32	30-35	28	25-30	30	30	30	19	12-25
Calcite	15	10-20	17	15-20	25	20-30	29	28-30	30	11	8-15
Feldspars	3	2-4	4	4	3	2-4	3	3-4	3	2	0-3
Hematite	11	10-12	13	10-15	14	10-20	10	8-12	10	9	8-10
Mica											
Combustion Products	(39)	26-57	(21)	16-26	(21)	13-26	(16)	12-20	(17)	(43)	22-65
Soot:											
Oil	32	20-45	15	10-20	18	10-25	9	8-10	10	22	20-25
Coal	2	2	1	0-2	1	0-2	2	1-2	2	<1	
Fine soot										19	0-38
Glassy fly ash	5	3-10	5	4-6	2	0-4	5	3-8	5	2	2
Incinerator fly ash					<1	0-1					
Burned wood											
Burned paper											
Magnetite											
Biological Materials	(<1)		(<1)		(<1)		(5)	<1-10	(<1)	(<1)	
Pollen	<1		<1				4	<1-8		<1	
Spores	<1		<1		<1		<1		<1	<1	
Paper	<1		<1		<1		<1			<1	
Starch	<1		<1		<1		<1		<1	<1	
Misc. plant tissue	<1		<1		<1		1	<1-2	<1	<1	
Miscellaneous	5	<1-10	(13)	10-15	(9)	5-12	(7)	5-8	(10)	(16)	6-25
Iron or steel	<1		<1		<1		<1		<1	<1	
Rubber	5	<1-10	13	10-15	9	5-12	7	5-8	10	16	6-25

Table B-8. CITYWIDE COMPOSITE SUMMARY OF FILTER ANALYSES IN PHILADELPHIA

No. of filters	26[a]	
	Quantity, percent	
Components	Average	Range
Minerals	(64)	6-93
Quartz	29	2-60
Calcite	19	1-68
Feldspars	2	0-5
Hematite	15	0-40
Mica	<1	
Other		
Combustion Products	(33)	6-89
Soot:		
Oil	8	0-60
Coal	2	0-15
Misc. soot	18	0-88
Glassy fly ash	5	0-30
Incinerator fly ash	<1	
Burned wood	<1	
Burned paper	<1	
Magnetite		
Carbon black		
Other		
Biological Material	(1)	0-10
Pollen	<1	
Spores	<1	
Paper	<1	
Starch	1	0-10
Misc. plant tissue	<1	
Leaf trichomer		
Miscellaneous	(2)	0-30
Iron or steel	<1	
Rubber	2	0-30
Other		

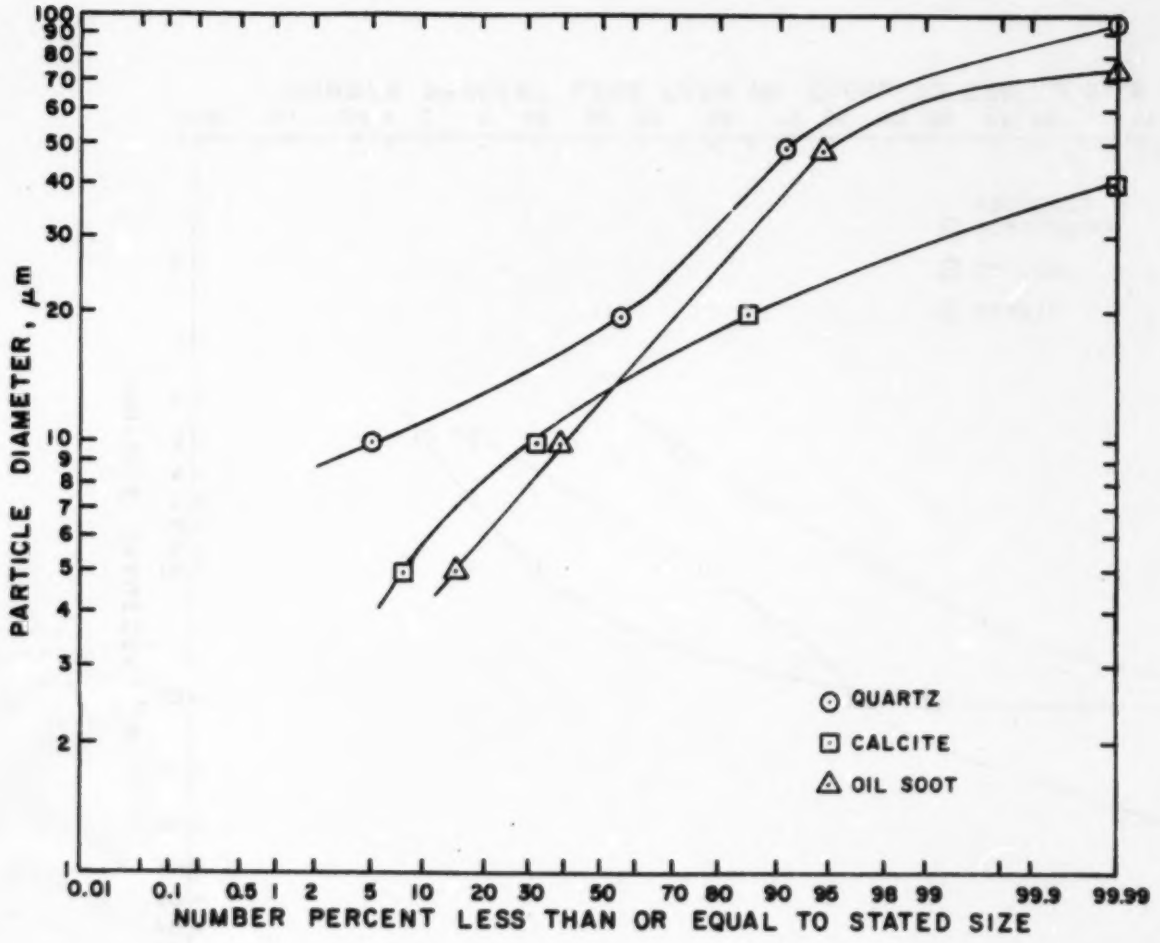

Figure B-1. Cumulative size distribution for three particle types, Broad and Spruce, Philadelphia, November 19, 1974.

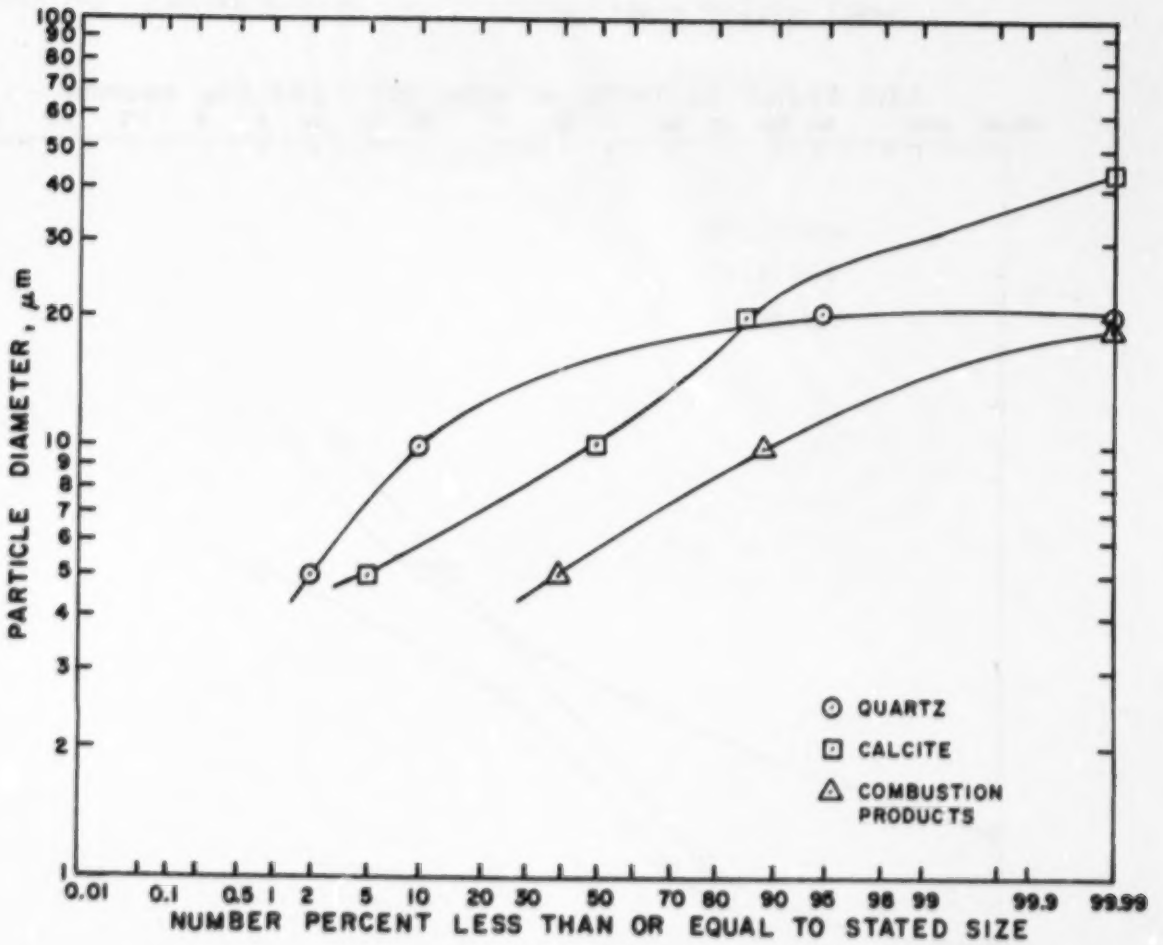

Figure B-2. Cumulative size distributions for three particle types, Broad and Lombard, Philadelphia, September 26, 1974

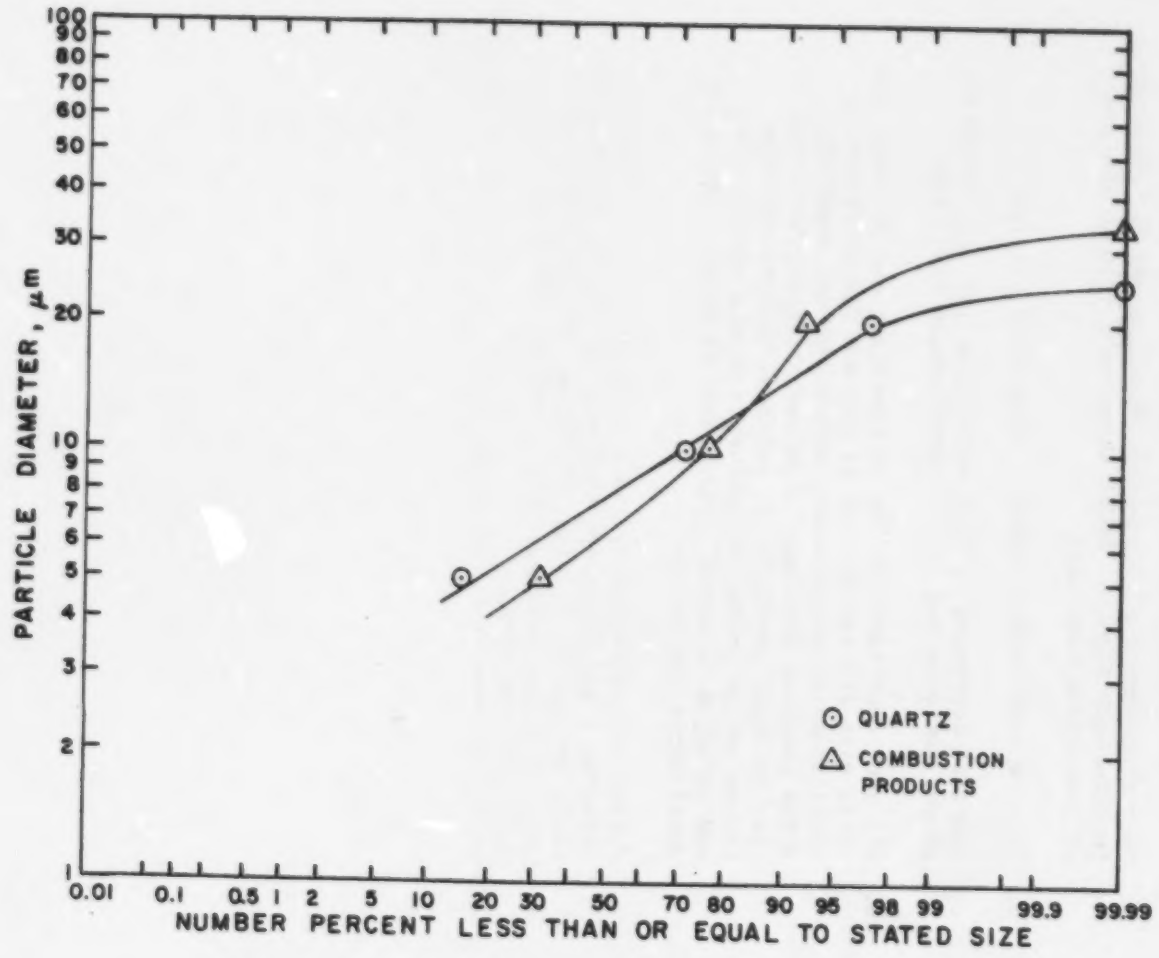

Figure B-3. Cumulative size distributions for two particle types, Broad and Lombard, Philadelphia, December 19, 1974

Table B-9. DETAILED PHYSICAL EXAMINATION: BROAD AND SPURCE, PHILADELPHIA, NOVEMBER 19, 1974

a. Quartz confirmed by dispersion staining and (-) uniaxial interference figure. EDXRA shows only silicon and trace of iron (from hematite).

b. Calcite confirmed by EDXRA - shows only calcium.

c. Hematite confirmed by high refractive indices, birefringence, and deep red color. EDXRA shows only iron.

d. Oil soot confirmed (as far as possible, due to small particle size and variability of fly ash due to operating conditions) by brittleness, morphology and especially EDXRA analysis showing: aluminum, silicon (both from clay feldspar impurities), calcium, sulfur, chlorine (there two as normal constituents of oil soots), iron and vanadium (a normal constituent of oils). The major constituent was carbon.

e. Rubber was confirmed by its elastomeric nature, surface appearance and EDXRA spectrum showing mostly carbon with minor amounts of calcium, aluminum, silicon (all probably from road wear products), sulfur, chlorine, iron, titanium, and zinc.

Table B-10. MONTHLY MEAN ALUMINUM LEVELS AT SELECTED PHILADELPHIA SITES FOR 1974, $\mu g/m^3$

Site	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
500 S. Broad	1.30	1.52	1.13	1.66	1.86	2.18	1.86	0.97	0.72	0.96	1.61	1.82	1.47
1501 E. Lycoming	1.36	1.26	1.48	1.32	1.99	1.96	1.68	1.05	0.95	0.90	0.89	2.17	1.50
S. E. Sewage	1.18	1.35	1.57	1.31	1.63	2.14	1.50	0.90	0.70	0.95	1.92	2.11	1.44

Table B-11. MONTHLY MEAN CADMIUM LEVELS AT SELECTED PHILADELPHIA SITES FOR 1974, $\mu g/m^3$

Site	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
500 S. Broad	.0044	.0031	.0039	.0029	.0032	.0036	.0048	.0018	.0051	.0044	.0070	.0042	.0041
1501 E. Lycoming	.0064	.0056	.0063	.0042	.0033	.0045	.0040	.0029	.0023	.0056	.0070	.0060	.0048

Table B-12. MONTHLY MEAN COPPER LEVELS AT SELECTED PHILADELPHIA SITES FOR 1974, $\mu g/m^3$

Site	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
500 S. Broad	0.161	0.079	0.076	0.079	0.098	0.239	0.211	0.485	0.361	0.208	0.140	0.163	0.192
1501 E. Lycoming	0.204	0.109	0.124	0.254	0.190	0.193	0.207	0.336	0.224	0.307	0.241	0.238	0.219

Table B-13. MONTHLY MEAN IRON LEVELS AT SELECTED PHILADELPHIA SITES FOR 1974, $\mu g/m^3$

Site	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
500 S. Broad	1.71	1.36	1.31	1.32	1.38	1.66	1.51	2.25	1.32	1.32	1.07	1.35	1.46
1501 E. Lycoming	2.18	1.50	1.59	1.62	1.79	1.77	1.55	1.68	1.48	1.43	1.37	1.57	1.63
S. E. Sewage	1.37	1.51	1.80	3.79	1.76	1.65	1.89	2.25	1.73	1.96	1.36	2.09	1.93

Table B-14. MONTHLY MEAN LEAD LEVELS AT SELECTED PHILADELPHIA SITES FOR 1974, $\mu g/m^3$

Site	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
1501 E. Lycoming	2.00	0.85	0.75	0.83	0.72	0.60	0.73	0.70	0.83	1.03	0.83	1.19	0.92
S. E. Sewage	1.11	1.13	1.11	1.31	1.24	1.13	1.06	1.26	1.38	1.57	1.44	1.38	1.26

Table B-15. MONTHLY MEAN MAGNESIUM LEVELS AT SELECTED PHILADELPHIA SITES FOR 1974, $\mu g/m^3$

Site	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
500 S. Broad	0.64	0.53	0.57	0.59	0.57	0.58	0.55	0.53	0.45	0.44	0.41	0.48	0.53
S. E. Sewage	0.64	0.66	0.62	0.57	0.61	0.47	0.47	0.49	0.40	0.39	0.44	0.52	0.52

Table B-16. MONTHLY MEAN NICKEL LEVELS AT SELECTED PHILADELPHIA SITES FOR 1974, $\mu g/m^3$

Site	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
500 S. Broad	0.065	0.059	0.037	0.035	0.031	0.023	0.017	0.021	0.032	0.031	0.034	0.039	0.035
1501 E. Lycoming	0.061	0.039	0.042	0.043	0.034	0.025	0.014	0.037	0.027	0.030	0.038	0.039	0.036

Table B-17. MONTHLY MEAN SULFATE LEVELS AT SELECTED PHILADELPHIA SITES FOR 1974, $\mu g/m^3$

Site	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
1501 E. Lycoming	39.6	21.6	18.3	21.5	19.0	17.4	16.4	19.5	21.5	24.0	22.4	21.4	21.9

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